CANCER AND FOOD INSECURITY:
EXPLORING PATHWAYS, PREDICTORS, AND GAPS IN MEASUREMENT.

A Thesis Presented

by

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to

The Faculty of the Graduate College

of

The University of Vermont

In Partial Fulfillment of the Requirements
for the Degree of Masters of Science
Specializing in Food Systems

October, 2025

Defense Date: September 9, 2025
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ABSTRACT

Food insecurity (FI) is an emerging concern in cancer care, yet the multiple mechanisms driving this vulnerability remain underexplored. Existing research largely emphasizes financial hardship—often measured using adaptations of the United States Department of Agriculture (USDA) food security survey module—as the primary contributor. While financial hardships, such as increased medical expenses and employment disruptions, are significant for cancer patients, FI may also result from non-financial factors, including physical limitations related to cancer and its treatment, transportation barriers, and lack of social support that hinder food procurement and meal preparation.

This thesis investigates predictors of FI among cancer patients at diagnosis and examines how cancer and its treatment influence FI through both financial and non-financial pathways after diagnosis. It draws on two studies to explore these issues. The first is a systematic literature review synthesizing evidence on FI and cancer using a food systems approach that considers both financial mechanisms (e.g., income loss, employment disruption, treatment costs) and non-financial mechanisms (e.g., physical impairments, transportation barriers, social isolation) linking cancer to FI after diagnosis. The second is a cross-sectional study that assesses the prevalence of FI at cancer diagnosis at a large medical center and identifies associated demographic and clinical predictors.

In the first study, the systematic review found that financial hardship was frequently documented, with income loss, work disruptions, increased medical expenses, and material hardship particularly prevalent among younger adults, lower-income individuals, and racially/ethnically minoritized populations. However, methodological limitations—especially the predominance of cross-sectional designs—restricted causal inference and understanding of how FI changes throughout treatment. Non-financial contributors were often overlooked in both measurement tools and study designs. The most commonly used measurement tool in the included studies was the USDA Household Food Insecurity Module, or an adaptation of it, which focuses exclusively on the financial aspects of FI.

In the second study, FI prevalence was 3.9%, lower than both state and national averages at the time of the survey, but disproportionately affected men, non-White patients, Medicaid recipients, and those with certain cancer types. Compared with both Vermont and national statistics, individuals of color were underrepresented in this dataset (97% White). Evidence from other studies indicates that marginalized populations often experience higher rates of FI.

FI among cancer patients is multifactorial, with non-financial barriers remaining underrecognized. Standard screening tools may underestimate need by focusing solely on financial access. These findings highlight the importance of improved measurement tools, longitudinal research, and integrated interventions that reflect the experiences of cancer patients—particularly in those most at risk.

ACKNOWLEDGEMENTS

First and foremost, I would like to thank my advisor, Meredith Niles, for planting the seed of thought for this topic, as well as for her thought-provoking guidance, insightful feedback, and continuous support, all of which have been invaluable throughout this research process.

I would also like to thank the members of my thesis committee: David Conner, whose course in food systems economics helped shape the background for this work; Emily Belarmino, for her thoughtful input in shaping the design of the systematic literature review; and Trishnee Bhurosy for her cancer research expertise and thorough, thoughtful feedback.

An additional heartfelt thank you to Christie Silkotch and Gary Atwood, whose library expertise supported the search strategy, as well as to Rebecca Mitchell, who gave time and energy to serve as the second reviewer for the systematic literature review—all of which made the review possible.

A special thanks to my colleagues and friends in the Food Systems program for fostering a collaborative and supportive environment, to my friends and family for the uplifting study breaks and motivation, and to Craig Compton for the unconditional love and support, as well as for providing economic research for Appendix A.

Lastly, thank you to my cat, Emmy, who will never read this, but who sat next to my laptop throughout graduate school these past two years and whose purrs always managed to calm my nerves and anxiety.

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CHAPTER 1: INTRODUCTION & FOOD SYSTEMS RELEVANCY

1.1. Introduction

"How a society treats its most vulnerable is always the measure of its humanity," is a quote often attributed to Mahatma Gandhi. Those facing poverty, health crises or disabilities, and individuals affected by political instability, war, or displacement are among those most vulnerable to conditions significantly impacting quality of life, and whom need close attention from both researchers and policymakers.

This thesis focuses on one vulnerable population, but one that faces multiple or multi-faceted challenges compared to other populations: individuals experiencing food insecurity—affecting approximately 2.33 billion people globally (Food and Agriculture Organization of the United Nations et al., 2024)—and those diagnosed with cancer, an estimated 20% of the global population (World Health Organization, 2024) and 38.9% of individuals in the United States (National Cancer Institute, n.d.) in a lifetime. More specifically, it examines food insecurity among individuals at risk for cancer and those undergoing cancer treatment, with attention to the demographic factors that increase vulnerability to both.

Although food insecurity and illness are global concerns, this thesis focuses on the United States—one of the only high-income OECD countries without a socialized healthcare system (Organization for Economic Co-operation and Development, n.d.). Instead of universal or near-universal coverage, the U.S. relies on a fragmented mix of federal and state programs, private insurance, and out-of-pocket spending. In 2022, the U.S. spent approximately $12,742 per person on healthcare—nearly double the average of $6,850 among other wealthy OECD nations—largely due to significantly higher health prices (Peter G. Peterson Foundation, n.d; Organization for Economic Co-operation and Development, 2022). This cost burden, coupled with limited safety-net coverage, creates barriers not only to medical care but also to securing adequate nutrition. Ongoing political debates over programs like Medicare, Medicaid, and food assistance continue to shape the structural environment in which individuals seek both healthcare and food access. Evidence suggests these systemic gaps have tangible

effects: in a national study of adults with chronic illness, those experiencing food insecurity were significantly more likely to report cost-related medication underuse, and individuals facing both food insecurity and cost-related underuse were less likely to have access to public health insurance or WIC (Berkowitz et al., 2014).

This research is grounded in the interdisciplinary field of food systems, which examines the complex interactions among food production and distribution, policy, economics, fair and safe labor practices, environmental sustainability, and social equity. FI is itself an inequity, shaped by many systemic issues within the food system. This thesis begins by exploring that foundation, but then dives a little deeper into the additional inequities that the healthcare system places on food insecurity. Together, these reveal how access to both food and care intersect to deepen vulnerability for cancer patients. These topics will be further explored throughout this chapter.

The chapters that follow examine the food insecurity definitions and measurements; the role of nutrition in cancer development, treatment, and survivorship; and food insecurity among cancer patients before and after diagnosis. Two primary deliverables guide this thesis: (1) a systematic literature review exploring the financial and non-financial mechanisms through which cancer and its treatment may influence food insecurity, and (2) a quantitative analysis assessing the prevalence and predictors of food insecurity among newly diagnosed cancer patients at an academic medical center.

Finally, this thesis offers recommendations to improve FI screening and support systems in survivorship care, highlighting opportunities to better meet the needs of those most at risk. These findings contribute to ongoing conversations about reducing health inequities and supporting patients through cancer care.

1.2. Food Systems Relevancy

The intersection of food insecurity and cancer is rooted in structural issues within the food system, including income inequality, market consolidation, food deserts and swamps, diet quality and affordability, sustainability, and the social determinants of health. Food insecurity itself is a

manifestation of inequity, shaped by multiple systemic forces. This chapter focuses on these food system drivers, establishing the foundation for understanding how broader inequities contribute to vulnerability.

1.2.1 Food Insecurity as a Systematic Issue

Food insecurity is a systemic issue influenced globally by factors like famine, natural disasters, war, and economic instability (*The State of Food Security and Nutrition in the World 2025*, 2025). In the United States, economic drivers are among the most significant, including low and stagnant wages, unemployment, inflation, rising food prices, unaffordable housing, and residential segregation (Elevating Voices: Insights Report, 2023). These factors place low-income households at particularly high risk of experiencing FI (Rabbitt et.al 2023). Despite being one of the wealthiest countries in the world, U.S. food insecurity rates have remained between 10% and 15% (U.S. Department of Agriculture, Economic Research Service, 2025), suggesting that economic growth alone is insufficient to eliminate food insecurity.

1.2.2 Income Inequality and Food Insecurity

Income inequality is a critical structural factor within the U.S. food system, shaping who has reliable access to adequate and nutritious food. While the United States' GDP has steadily increased (U.S. Bureau of Economic Analysis, n.d.), food insecurity rates have remained relatively constant. This suggests that economic growth has not translated into equitable wealth distribution and that economic inequality has worsened (World Bank, n.d.). A disproportionate share of wealth continues to accumulate among affluent populations, while lower-income households struggle with financial strain. Between 1989 and 2016, the disparity in wealth between the richest and poorest families in the U.S. more than doubled. In 1989, families in the top 5% held about 114 times the wealth of those in the second-lowest income group ($2.3 million versus $20,300). By 2016, this gap had widened

significantly, with top earners possessing 248 times more wealth (Horowitz, Igielnik, & Kochhar, 2020).

Few studies directly examine the relationship between income inequality and food insecurity. To explore this gap, an economist colleague conducted a regression analysis (Appendix 1) showing a positive correlation: for every 0.01 increase in the Gini index (a measure of income or wealth inequality within a country or economy), food insecurity rises by 0.5 percentage points. This finding aligns with prior literature indicating that greater income disparity exacerbates economic hardship for lower-income households (Jachimowicz et al., 2020).

1.2.3 Market Consolidation and Food Deserts

Market concentration in food retail has been increasing and entry of a large chain retailer is associated with a decrease in independent food retailers, particularly in rural communities (Çakır et al., 2020). This contributes to the rise of food deserts—areas with limited access to affordable, nutritious food. For example, dollar store chain expansion has led to a large decline in the number of grocery stores – for every three new dollar stores the market loses one grocery store – additionally, dollar store chain expansion is associated to a significant decrease in fresh produce consumption, particularly for households who are low income, older, from minority groups, or without access to a vehicle (Caoui, Hollenbeck, & Osborne, 2022).

1.2.4 Diet Quality, Chronic Disease, and Food Affordability

Poor dietary quality is a well-established risk factor for chronic diseases, including many cancers. In the U.S., dietary quality is influenced by a complex interplay of factors, including market power and marketing strategies, which heavily shape consumer food choices (Nestle, 2007). Nutrient-poor, energy-dense foods are often cheaper than nutrient-dense options, widening disparities (Darmon & Drewnowski, 2015).

Federal subsidies for agriculture contribute to this gap, as the majority are directed toward commodity crops—such as corn, soybeans, and wheat —which are often used as base ingredients in processed food products (Environmental Working Group, n.d.). While these crops have nutritional

value, especially in their whole form, the concern lies in the disproportionate subsidies favoring these over fresh fruits and vegetables, which are essential in chronic disease prevention.

Measuring the impact of dietary quality on cancer risk is complex due to varying definitions and measurements for dietary quality (ex. dietary patterns, produce consumption, sugar sweetened beverage consumption) and multiple cancer types. Still, strong evidence supports protective effects of high-quality diets in minimizing cancer risk. For example, in a systematic literature review, higher dietary quality was linked to reduced pancreatic cancer risk (J. Zheng et al., 2017). In a meta-analysis the Mediterranean diet was linked to reduced oral and oropharyngeal cancer risk (Shrivastava et al., 2024). In a study with 48,421 participants, a DASH-aligned diet was associated with lower lung cancer risk—even among smokers (Wang et al., 2021). And in another study, higher healthy eating index scores predicted a lower risk of lung and colorectal cancer (Park et al., 2021).

However, food insecurity presents a challenge in achieving recommended diet quality. A systematic review confirmed the inverse relationship between food insecurity and diet quality (Hanson & Connor, 2014), Additional research has shown that food-insecure individuals tend to consume fewer fruits and vegetables and more red and processed meats, high-fat dairy products, and sugar-sweetened beverages, resulting in lower Healthy Eating Index scores (Leung et al., 2014).

1.2.5 The Social Determinants of Health

Finally, this thesis situates food insecurity within the broader framework of the Social Determinants of Health (SDOH). According to Healthy People 2030, health is shaped by interconnected factors including economic stability, education, the environment, community context, food access, and the healthcare system.

These factors can influence one another, with food largely being impacted by social, economic, and environmental factors. This study looks closer at the relationship between healthcare and food related to the expense of cancer treatment, as well as other system-level ways in which cancer treatment may affect food security. Addressing these disparities requires interventions that address underlying social and economic inequalities, such as improving access to affordable, healthy

food in low-income communities and addressing structural barriers to food access, all of which relate to the topic of food systems.

1.2.6. From Food Systems to Healthcare Systems

Understanding FI through the lens of the food system provides a foundation for this thesis; the next chapter expands this perspective by examining how healthcare system inequities and the burdens of illness further compound vulnerabilities.

CHAPTER 2: LITERATURE REVIEW

Introduction

This chapter explores how food insecurity (FI) emerges and manifests in the context of cancer care. While Chapter 1 situated FI within the broader food system, here the focus narrows to the unique challenges faced by individuals undergoing cancer treatment and survivorship. To guide this discussion, the Food and Agriculture Organization's (FAO) four domains of food security—availability, access, utilization, and stability—are applied as a food systems framework. Using this lens allows for a holistic examination of how cancer and its treatment may disrupt not only financial access to food, but also the physical, social, and systemic conditions that shape nutrition security across the care continuum.

2.1 Defining and Measuring Food Insecurity

2.1.1 FAO Definitions and Measures

The Committee on World Food Security defines food and nutrition security as existing "when all people, at all times, have physical, social, and economic access to food that is safe and consumed in sufficient quantity and quality to meet their dietary needs and food preferences, supported by an environment of adequate sanitation, health services, and care, enabling a healthy and active life." This definition comprises four domains: availability, access, utilization, and stability (Committee on World Food Security, 2012). In this thesis, these domains are used as a food systems framework to examine how cancer and its treatment may influence FI. Availability refers to the amount of food present in a country or region through domestic production, imports, food stocks, and food aid. Access is the ability to obtain appropriate foods for a nutritious diet through physical, economic, and social means. Utilization involves the proper use of food to achieve adequate nutrition, supported by clean water, sanitation, and health care. Stability means having consistent access to adequate food at all times, without risk of disruption due to economic, climatic, or political factors (Food and Agriculture Organization [FAO], 2006; World Bank, n.d.). In 2022, two additional elements—sustainability and agency—were proposed to expand this framework, although they have

not yet been formally adopted. Agency refers to the capacity of individuals and groups to exercise voice and make decisions about their food systems. Sustainability refers to the long-term viability of the ecological and social foundations of food systems (Clapp et al., 2022).

Table 2 summarizes these definitions, along with indicators and measures drawn from various sources. As noted in a systematic literature review by Manikas (2023), there is no uniform consensus on the best measurement approach for all four domains. The FAO (2013) similarly observes that "measuring the complexity of food security is part of a broader debate currently taking place in the preparation process of the post-2015 development agenda." Given the complex, multilevel nature of food insecurity, it makes sense to use a variety of indicators, data sources, and survey modules rather than relying on a single measurement tool to capture all aspects of the issue.

Table 1:

The 6 Domains of Food Insecurity Across the Literature

Domain	Definition	Indicators	Measures
Availability	The amount of food present in a country or region through domestic production, imports, food stocks, and food aid	-Average dietary energy supply[1] -Average value of food production[1] -Average protein supply[1] -Average supply of protein of animal origin[1] -Home food production[3]	POU[4], GFSI[4], Suite of Food Security Index[4], crop yields, food imports/exports, food balance sheets, market inventories
Access	The ability to obtain appropriate foods for a nutritious diet through physical, economic, and social means	-Percentage of paved roads over total roads[1] -Road and rail line density[1] -Domestic food price index[1] -Prevalence of undernourishment[1] -Share of food expenditure of the poor[1] -Prevalence of food inadequacy[1]	HFSSM[4], FIES[4], HHS[4], GHI[4], GFSI[4], HDDS[4], FCS[4], CSI[4], Suite of Food Security index[4], food price data, proximity to grocery stores via GIS
Utilization	The use of food through adequate diet, clean water,	-Access to improved water sources[1] -Access to improved sanitation facilities[1]	GFSI, Suite of Food Security Index, 24-hour

	sanitation, and health care	-Percentage of children under 5 years of age affected by wasting, stunting, and who are underweight[1] -Percentage of adults who are underweight[1] -Prevalence of anemia among pregnant women and among children under 5 years of age[1] Prevalence of vitamin A and iodine deficiency[1]	GHI[4], GFSI4, anthropometry measures[4], Suite of Food Security index[4], dietary recalls, FFQs, dietary diversity scores, micronutrient biomarkers
Stability	Consistent access to adequate food at all times, without risk of disruption due to economic, climatic, or political factors	-Percentage of arable land equipped for irrigation[1] -Value of food imports over total merchandise exports[1] -Political stability and absence of violence/terrorism[1] -Domestic food price volatility[1] -Per capita food production variability[1] -Per capita food supply variability[1]	GFSI[4], Suite of Food Security Index[4], longitudinal surveys, seasonal recall of food insecurity, price volatility, agricultural variability
Agency	The capacity of individuals and groups to exercise voice and make decisions about their food systems	-Women's decision-making, status of employment, and perceptions of domestic violence, as well as agency in farming[2] -Clear labeling and nutrition information that includes the social, economic, and environmental conditions of food production giving power to consumers in their purchasing and consumption choices[2] -Data on individuals participation in local food systems decision-making and governance such as municipal food security councils[2] -National commitments to uphold the right to food and other human rights[2] -Levels of national food self-sufficiency[2] -Numbers and types of food producers[2] -Measures of domestic market concentration[2]	WEN[2], WENI[2], FIES[2]

		-Participation in member-based associations, cooperatives and unions[2] -Rates of farmer suicide[2] -The prevalence of fair trade[2]	
Sustainability	The long-term viability of the ecological and social bases of food systems	-Productive and sustainable agriculture[2] -Soil health parameters, agrobiodiversity indicators, agrochemical use, water quality, and adherence to voluntary sustainability certification system[2] -Energy input/output type analysis[2] -Assessments of the sustainability of diets[2] -Resilience indicators for food systems, incorporating biophysical capacity, production diversity, and socioeconomic access[2] -Agroecology indicators[2]	Seven Food System Metrics of Sustainable Nutrition Security[2], Measurement tool for three dimensions of resilience[2], sustainability certification data

Note. This list is not comprehensive, but illustrative. [1]Food and Agriculture Organization of the United Nations [FAO], 2013; [2]Clapp et al., 2022; [3]Ashby et al., 2016, [4]Manikas et al, 2023
Abbreviations Used in Measures: HFSSM = Household Food Security Survey Module; FIES = Food Insecurity Experience Scale; HHS = Household Hunger Scale; HDDS = Household Dietary Diversity Score; FCS = Food Consumption Score; CSI = Coping Strategy Index; GHI = Global Hunger Index; GFSI = Global Food Security Index; WEN = Women's Empowerment in Nutrition grid; WENI = Women's Empowerment in Nutrition Index; FFQs = Food Frequency Questionnaires.

Notably, these domains can be examined at regional, national, household, or individual levels, though many measurements are conducted at the regional or national scale.

Two systematic reviews—Ashby et al. (2016) and Manikas et al. (2023)—found that most food insecurity measurement tools in the literature emphasize the access domain, particularly financial access to food, while underrepresenting availability, utilization, and stability. This emphasis likely reflects the U.S. Department of Agriculture Economic Research Service (2025) definition of FI as difficulty providing enough food for all household members due to insufficient resources at some

point during the year. By centering on financial barriers, this definition shapes the design of the primary U.S. measure: the Household Food Security Survey Module (HFSSM).

2.1.2: Limitations of the Household Food Security Survey Module

The HFSSM, widely used in the United States, primarily measures financial barriers to food and concerns about running out of food. By capturing only one aspect of access – economic constraints -- it fails to capture the domain's full scope, let alone other dimensions of food security. As the Food and Agriculture Organization of the United Nations (2013) explains: "The ability to access food rests on two pillars: economic and physical access. Economic access is determined by disposable income, food prices and the provision of and access to social support. Physical access is determined by the availability and quality of infrastructure, including ports, roads, railways, communication and food storage facilities and other installations that facilitate the functioning of markets." The HFSSM does not account for these physical access issues.

The HFSSM also does not capture aspects of the utilization domain, including access to clean water, sanitation, dietary diversity, or micronutrient deficiencies. Physical limitations in procuring food (e.g., grocery shopping), preparing food, and self-feeding can also be considered elements of the utilization domain. The concept of nutrition insecurity—defined as consistent and equitable access to healthy, safe, and affordable foods essential for optimal health and well-being—most directly aligns with the FAO's utilization domain, which emphasizes dietary quality, nutrient adequacy, and health outcomes. However, nutrition insecurity is also shaped by availability, access, and stability, since all domains affect the ability to consistently obtain and use nutritious foods for a healthy life. For example, in an ethnographic study conducted in a rural county in Oregon, some participants who were categorized as food secure using the HFSSM still reported living on macaroni and cheese or ramen noodles to stretch resources until they could afford healthier options (Gross, J., and N. Rosenberger 2005), which would be considered nutrition insecurity.

The HFSSM is typically administered using a 12-month recall period (or 30 days in some adaptations), but it does not capture seasonal variability, shocks, or long-term stability in food

security. It cannot identify cyclical or temporary crises that undermine consistent access to food. For example, during the COVID-19 pandemic, supply chain disruptions in production and distribution reduced the availability of many items and increased food prices (U.S. Department of Agriculture, Economic Research Service, 2025), and contributed to variable changes in food security (Kim-Mozeleski et al., 2023).

The HFSSM also does not provide information about the overall availability of food in a region or community, as it is explicitly designed to measure food security at the household—not regional or national—level.

Lastly, the tool may effectively capture severe food insecurity but overlook less severe, borderline, or variable food insecurity. It may also fail to adequately capture the experiences of individuals who are chronically ill, elderly, or functionally impaired. For example, in a study of US adults aged 60 years and older, most participants faced physical access challenges rather than economic barriers to food (25% vs. 4.4%) (Vaudin et al., 2022).

In recent years, there have been efforts to broaden how food insecurity is conceptualized in the United States. The Biden-Harris administration included nutrition security in their National Strategy on Hunger, Nutrition, and Health (The White House, 2022). However, the USDA has not yet established a formal metric to assess it.

These gaps underscore the need for more comprehensive, multidimensional measurement approaches aligned with the full FAO framework. This thesis contributes to this effort by applying

the four-domain framework to the context of cancer care, providing a foundation for examining FI in this population.

2.1.3 FAO Domains' Application to Cancer Care

This thesis aims to encourage a broader understanding of food insecurity through the lens of the FAO's four domains. Cancer patients provide a unique opportunity to explore other domains. Table 2 includes theorized indicators for food insecurity among cancer patients.

Table 2:

Theorized Indicators for Food Insecurity among Cancer Patients in the USA

Domain	Theorized Indicators
Availability	Disruptions to at-home food production due to treatment
Access	Financial (medical financial hardship, work disruptions) Physical limitations procuring food (ex. grocery shopping) Transportation issues Residence in a food desert
Utilization	Physical limitations preparing food and self-feeding Malnutrition diagnosis Physiological impacts of cancer and it's treatment that hinder adequate dietary intake and quality (e.g., dysgeusia, dysphagia) Lack of medical nutrition therapy (MNT) coverage for dietitians to diagnosis and work with patients with food related challenges Limited household food preparation equipment Limited access to safe water and sanitation Lack of diet diversity
Stability	Periods of running low on food during the month or year (e.g., treatment-related fluctuations) Changes in food security over time as assessed at clinic visits Food related disruptions related to COVID-19

Availability: For oncology patients, this domain may be affected in less conventional ways. For example, individuals who rely on at-home food production (gardening, hunting, preserving) may

find that treatment side effects, fatigue, or physical decline limit their ability to maintain these practices, although there is limited research in this area.

Access: Access includes both economic and physical ability to obtain food. In cancer care, financial strain is well documented and elaborated on later in this thesis. Less researched is physical access. One study measuring "physical food insecurity" through activities of daily living (ADLs) found that 30.7% of older adults with cancer had trouble shopping for groceries, carrying food, or preparing meals (Vaudin et.al., 2022). Transportation insecurity is also common, ranging from 5.6% to 25% of patients (Aziz-Bose et.al, 2024; Hao et.al., 2024; Rosenberg et.al., 2024; Valenzuela et.al., 2023). In one study, fewer than half of cancer patients reported driving themselves to grocery stores, while others relied on rides, walking, or public transit; notably, 6% did not shop at grocery stores at all (Luo et.al.,2023)

Utilization: Utilization includes many facets including the physical limitations of preparing food and self-feeding, how food is biologically used, healthcare support, and food safety. In Shi 2023 up to 91.3% of participants reported that cancer and its treatment affected their ability to perform typical household responsibilities, while Luo 2023 another found that 58.5% reported difficulty doing chores.

Another area of utilization could be the physiological impacts of cancer and it's treatment that hinder adequate dietary intake and quality (e.g., dysgeusia, dysphagia). Treatment side effects, disease-related metabolic changes, and functional impairments can severely limit food intake and nutritional status even when food is available. For example, dysgeusia has been reported in 14–100% of patients receiving chemotherapy or radiotherapy, with the highest prevalence in head and neck cancers (Pombo et al., 2022). Among oral cancer patients, 70% report dysgeusia, which can lead to weight loss and malnutrition (Ghias et al., 2023; Togni et al., 2021).

Interventions such as oral nutrition supplements (ONS) and medical nutrition therapy (MNT) can mitigate these challenges, improving nutritional status and outcomes (Moloney et al., 2025a; Movahed et al., 2020); However, both ONS and MNT are poorly covered by insurance, with

policies varying by state and payer (Academy of Nutrition and Dietetics, 2025; Caccialanza et al., 2022). The limited coverage of these essential services creates a gap in utilization support.

Stability: Stability reflects the consistency of food security over time. For cancer patients, stability is threatened by treatment-related fluctuations. Patients may have sufficient resources one month but struggle in another due to medical bills, reduced income, or acute side effects that limit their ability to access or prepare food. Several longitudinal studies find financial FI to increase over time: Among the six studies that examined FI longitudinally -- three retrospective cross-sectional (Evans et.al., 2023; Lin et.al., 2024; McDougall et.al., 2020), two prospective cohorts (Aziz-Bose et.al., 2024; Bona et.al., 2016) and one RCT (McDougall et.al., 2024)-- all reported increases. One increase was not statistically significant (Aziz-Bose et.al., 2024) and two did not test significance (McDougall et.al., 2020; McDougall et.al., 2024).

The COVID-19 pandemic further demonstrated the stability domain. Early surveys (March-April 2020) found a 32.3% increase in household food insecurity in a statewide survey of Vermont, with over one-third of cases classified as "newly food insecure"(Niles et al., 2020). While less is known about cancer-specific COVID-19 impacts, these disruptions underscore how external shocks compound vulnerabilities for patients already navigating treatment-related challenges.

Recognizing the relevance of the FAO domains to cancer care highlights important gaps in how food insecurity is currently measured among oncology patients. While theoretical frameworks can guide our understanding in the diverse contributors to food insecurity, measurement tools often fall short of capturing this complexity. To address this gap, Appendix B specific measurement items aligned with the FAO domains that could be adapted or developed for use in cancer care settings.

2.2. Nutrition Related Challenges During Cancer Treatment

Cancer patients often face unique nutrition-related complications that make adequate intake a critical clinical consideration beyond issues of food insecurity. Malnutrition is highly prevalent in oncology, affecting an estimated 20–70% of patients depending on tumor type, disease stage, and care setting (Arends, 2024). The American Society for Parenteral and Enteral Nutrition (ASPEN) (2018)

defines malnutrition as an acute, subacute, or chronic state of nutrition in which varying degrees of overnutrition or undernutrition, with or without inflammatory activity, result in altered body composition and impaired function.

Malnutrition in cancer typically arises from a combination of inadequate intake and disease-specific metabolic disturbances (Arends, 2024). Inadequate intake can result from symptoms such as anorexia, nausea, taste and smell changes, dysphagia, vomiting, mucositis, diarrhea, and abdominal pain. Functional barriers such as impaired chewing, fatigue, or tumor obstruction may also impede intake. Meanwhile, metabolic disturbances in cancer are driven by tumor- and host-mediated inflammatory responses that increase resting energy expenditure, promote loss of lean body mass, and disrupt anabolic signaling. This catabolic process—characteristic of cancer cachexia—can persist even when dietary intake is adequate, distinguishing it from starvation (Arends, 2024).

In the United States, the American Society for Parenteral and Enteral Nutrition (ASPEN) criteria are the standard for diagnosing malnutrition, requiring the identification of two or more of six characteristics: reduced energy intake, weight loss, loss of muscle mass, loss of subcutaneous fat, fluid accumulation, and diminished functional status (e.g., reduced handgrip strength). However, these criteria do not account for metabolic disturbances, so a malnutrition diagnosis alone cannot determine whether the cause is cancer itself, reduced intake related to treatment side effects, or reduced intake related to food insecurity. This distinction is important when interpreting food insecurity research, as discussions of malnutrition can sometimes blur whether inadequate intake results from food access issues or the underlying disease process itself.

Malnutrition is a critical concern for cancer patients because it's associated with a range of poor clinical outcomes. Observational studies comparing malnourished patients to well-nourished patients, found higher rates of treatment-related toxicity (Hsueh et al., 2021; Jain et al., 2020), chemotherapy dose reductions for toxicity (Klute et al., 2016), treatment discontinuation (Findlay et al., 2021), emergency room visits (Hsueh et al., 2021), hospitalizations (Findlay et al., 2021; Hsueh et al., 2021), and mortality (Eglseer et al., 2021; Jain et al., 2020; Zhang et al., 2021) among malnourished

patients. A meta-analysis also found that malnutrition increases the risk of all-cause mortality (X. Zhang et al., 2019). It is estimated that 10–20% of cancer-related deaths are attributable to malnutrition rather than the cancer itself (Muscaritoli et al., 2021).

These risks make early detection and intervention critical. The European Society for Clinical Nutrition and Metabolism (ESPEN) has evidence-based guidelines for identifying, preventing, and treating reversible elements of malnutrition in adult cancer patients. Recommendations include ensuring adequate energy intake (25–30 kcal/kg/day, accounting for elevated resting energy expenditure offset by reduced physical activity during treatment), higher protein needs (>1.0 g/kg/day, up to 1.5 g/kg/day when possible), and maintaining micronutrient intakes within recommended daily allowances. Oral nutrition supplements (e.g., Boost, Ensure, Carnation Instant Breakfast) are recommended when diet alone is insufficient, alongside individualized nutrition counseling. Enteral nutrition (EN) or parenteral nutrition (PN) may be necessary in certain cases, although these options are costly and not always fully covered by insurance (EN approx. $150–1,000/month; PN $4,500–20,000/month). Best practice includes multimodal care that combines nutrition counseling, symptom management, physical activity, psychosocial support, and addressing the social determinants of health.

Screening and managing malnutrition from diagnosis onward can help prevent treatment interruptions, improve therapy tolerance, and enhance patient well-being. Nutrition support can improve energy intake, body weight, and quality of life in at-risk or malnourished cancer patients (ESPEN, 2021). However, nutritional interventions have not consistently demonstrated improvements in overall survival. As Arends et al. (2023) note, "improving survival of cancer patients by preventing or successfully reversing malnutrition so far has been in most settings an elusive goal." This may be partly due to the difficulty of reversing cancer cachexia specifically, compared to malnutrition resulting from inadequate intake.

Clinical nutrition challenges impact all cancer patients, but would be especially burdensome for those experiencing food insecurity, lapses in health insurance, or lacking close family and friends to help manage food-related challenges. Financial strain, limited access to healthy foods, and the high

costs of nutritional support can further compound the risks of malnutrition and worsen treatment outcomes. Even though nutrition challenge are high in this population, unfortunately most cancer patients never receive a nutritional counseling during their treatment course (Arends et al., 2017; Bhurosy et al., 2022).

The following section explores food insecurity's relationship to cancer and its treatment.

2.3 Food Insecurity among Cancer Patients

2.3.1 Prevalence in Food Insecurity Among Cancer Patients

Cancer patients may be more vulnerable to food insecurity than the general population. A 2023 scoping review found that prevalence estimates among 15 studies range from 4.0 to 83.6% (Robien et al., 2023). This compares to the U.S. average, where an estimated 10.5% of households are food insecure (Coleman-Jensen et al., 2021). The variation in reported prevalence was attributed to several factors. Some studies focused on low-income, underserved populations—such as patients at Federally Qualified Health Centers (FQHCs)—which reported much higher rates of food insecurity (up to 83.6%). When these populations were excluded, prevalence estimates ranged from 4.0% to 26.2%, closer to national averages. Other studies examined different phases of cancer care, with some focusing on patients in active treatment and others on survivorship- groups that may have different financial needs. Sociodemographic factors were also associated with differences in food insecurity rates, with consistently higher prevalence among Hispanic and non-Hispanic Black patients, and several studies finding higher rates among younger patients. Unfortunately, few studies examined prevalence by cancer site or treatment.

The authors concluded that due to heterogeneity in study populations and sample sizes, it was not possible to estimate an overall prevalence of food insecurity among cancer survivors (considered to be those in active treatment or post-treatment). Few studies lacked controls to non-cancer populations making it hard to compare. Importantly, many studies did not specify how far patients were into treatment or track food insecurity over time. Food security status at the beginning of

treatment may not reflect the financial burden of prolonged treatment or capture changes in food insecurity during care.

Of studies measuring over time, one study following families of pediatric cancer patients in treatment found an increase in food insecurity from 11% at diagnosis to 20% six months later (Bona et al., 2016). Another study retrospectively asked adult participants about food insecurity a year before and a year after treatment, finding that 10% became newly food insecure and 26% were persistently food insecure (McDougall et al., 2020).

Given the critical importance of nutrition for cancer outcomes, more research is needed to better understand the prevalence of food insecurity and its contributing factors. As will be discussed in subsequent sections, food insecurity is itself a risk factor for chronic disease. The medical, financial, and non-financial hardships associated with cancer and its treatment also increase vulnerability to food insecurity. As McDougall (2020) eloquently summarizes, "the relationship between food insecurity and chronic illness is bidirectional or cyclic, with chronically ill individuals facing financial challenges leading to food insecurity and food-insecure individuals being forced to make a trade-off between food and medical care, leading to poor health outcomes and exacerbating financial hardship." Although fully disentangling this relationship is complex, this thesis seeks to clarify it by examining predictors of food insecurity among those diagnosed with cancer and exploring how food security status may change following diagnosis

2.3.2 Leading up to Diagnosis: Baseline Food Insecurity Risk

Food insecurity is also a predictor of a diagnosis. A USDA report found that among working-age adults living at or below 200% of the federal poverty line, food security status was more strongly correlated with cancer and 10 other chronic conditions than income alone. The risk increased progressively with worsening food security, from marginal to very low food secure categories (Gregory & Coleman-Jensen, 2017). Additional publications have found food insecurity to be associated with chronic disease, mental health issues, and malnutrition (Gundersen & Ziliak, 2015; National Institute

Health, 2024). The reasoning for this is likely a complex interplay of factors, many of which lie within the social determinants of health.

Food insecurity is associated with poorer diet quality (Hanson & Connor, 2014; Leung et al., 2014; Vaudin et al., 2022) which is a known risk factor for many chronic diseases including cancer. A systematic review found that food-insecure adults consumed fewer fruits, vegetables, and dairy products, with lower intakes of vitamin A, vitamin B-6, calcium, magnesium, and zinc compared to food-secure adults (Hanson & Connor, 2014). This association can be attributed to many factors not limited to limited financial resources, stress, and food environment factors. Numerous studies have linked dietary quality to cancer risk (Zheng et al., 2017; Shrivastava et al., 2024; Wang et al., 2021; Park et al., 2021).

Food insecurity is also associated with higher rates of tobacco use and excessive alcohol consumption—known cancer risk factors (Bergmans et al., 2019). Food insecurity is linked to elevated depression and stress (Pourmotabbed et al., 2020), which may impair a patient's ability to maintain health and seek necessary care.

Regarding healthcare access, in a nationally representative study, food-insecure individuals reported less health insurance coverage and establishment with a usual source of care compared to their food-secure counterparts (Pruitt et al., 2016). Another study found that food insecure individuals had an increased risk of healthcare access hardship including being unable to afford doctor visits or medications (Charkhchi et al., 2018), with at least one in four reporting a lack of transportation, insufficient funds for medical visits, or an inability to secure an appointment (Mitchell et al., 2025).

Paradoxically, those who are food insecure have higher healthcare utilization. A longitudinal U.S. study found that food-insecure adults had significantly higher rates of emergency department visits, inpatient admissions, and longer hospital stays compared to food-secure adults, as well as increased healthcare expenditures (Berkowitz et al., 2018). A retrospective U.S. health system analysis found that patients with food insecurity were less likely to have provider office visits after hospital discharge and over twice as likely to utilize acute care within 90 days compared with those without

food insecurity (Distelhorst et al., 2023). An interpretation could be that food insecurity is associated with less preventative and long-term care and more acute care for major issues.

Screening rates, which is more consistent in literature, would support this idea. In a national survey, food insecurity was linked to significantly lower odds of being up to date on colorectal cancer screening (Lei et al., 2023). Similarly, food insecurity was associated with reduced breast cancer screening (Mahmood et al., 2023; Mendoza et al., 2022).

2.3.3 Prevalence and Predictors at Diagnosis

In the studies specifically looking at FI at diagnosis (not during treatment or post-treatment), FI rates exceed the U.S. national average of 10.5% (Coleman-Jensen et al., 2021). For example, among pediatric patients, FI was reported in 53% with newly diagnosed acute lymphoblastic leukemia (Aziz-Bose et al., 2024), 11% undergoing chemotherapy (Bona et al., 2016), and 22% in another cohort at diagnosis (Evans E.M. et al., 2023). In adults, 29% with stage I–III breast, colorectal, or prostate cancer retrospectively reported FI in the year before diagnosis (McDougall et al., 2020) and 21% of those evaluating surgery for suspected lung or gastrointestinal malignancies reported FI (Van Haren et al., 2024).

Few of these studies examined demographic factors linked to FI at diagnosis. In the pediatric cohort, low-income families were significantly more likely to report material hardship—including food insecurity—than wealthier families ($p < 0.001$) (Bona et al., 2016). This limited research leaves a gap in understanding predictors of FI at diagnosis.

Nationally, food insecurity rates (not specific to cancer) are higher among certain populations: households with children (17.9%); single female– and single male–headed households with children (34.7% and 22.6%); women living alone (16.2%); households with Black (23.3%) and Hispanic (21.9%) members; households below 100% of the federal poverty line (38.7%), below 130% (37.3%), and below 185% (33.5%); households in principal cities (urban, 15.9%) and nonmetropolitan (rural, 15.4%) areas (excluding suburbs, which are lower); and households in the South (14.7%) (USDA's Economic Research Service). Given these disparities, it is reasonable to expect higher FI rates at cancer diagnosis

among these groups. Some of these predictors also align with studies examining FI during active treatment and post-treatment.

2.3.4 Who is predicted to struggle the most with food insecurity during treatment and in survivorship?

As noted earlier, the scoping review identified several sociodemographic factors associated with higher food insecurity rates among cancer patients. These included low-income individuals receiving care at FQHCs, Hispanic and non-Hispanic Black patients, and younger patients. Additional studies support these associations, finding that low income (Camacho-Rivera et al., 2022), younger age (Bhurosy et al., 2025; Camacho-Rivera et al., 2022), and non-Hispanic Black and Hispanic/Latina race and ethnicity (Rosenberg et al., 2024) are consistently linked to higher food insecurity risk.

Other factors associated with elevated risk include living in rural areas, facing transportation barriers, and experiencing housing instability (Camacho-Rivera et al., 2022; Van Haren et al., 2024). Insurance coverage also plays a role: patients who are uninsured (Camacho-Rivera et al., 2022; McDougall et al., 2020), enrolled in Medicaid (McDougall et al., 2020), or on public insurance more broadly (Zheng et al., 2020) tend to have higher odds of food insecurity. Additional risk factors identified in the literature include lower educational attainment (Camacho-Rivera et al., 2021), unmarried status (McDougall et al., 2020), higher levels of debt (McDougall et al., 2020), and greater burden of comorbidities (McDougall et al., 2020; Zheng et al., 2020).

Cancer type may also influence risk. Only three studies in the scoping review examined food insecurity prevalence by cancer site. One analysis focusing on cancers of the throat or pharynx, thyroid, and colon found significantly higher prevalence among individuals with throat or pharynx cancers compared to those with thyroid or colon cancers. Two additional studies reported high prevalence of food insecurity (over 50% of participants) among low-income patients receiving treatment at FQHCs in New York City, regardless of cancer site (Robien et al., 2023).

2.3.5 Financial Hardship in Treatment

Diagnosis and treatment can introduce significant financial hardships that increase the risk of food insecurity, through both direct medical expenses and indirect costs such as disrupted employment. Medical expenses may include diagnostic tests, doctor visits, treatments, procedures, imaging, hospital stays, home care, and specialist consultations. Non-medical costs may include transportation (especially for those traveling out of town or state), lost wages, and household or family care expenses (e.g., paying for childcare typically provided by the cancer patient).

Cancer is among the most expensive diseases to treat, with the national patient economic burden estimated at $21 billion in 2019 (Yabroff et al., 2021). On an individual level, this is a large cost. Using the SEER-Medicare database, Mariotto et al. (2020) estimated costs by cancer site and phases of care for those survivors aged ≥65 years on Medicare. Care phases include: initial (first year after diagnosis), continuing (the time between initial and end-of-care), and end-of-life (the final year before cancer death). For initial care, costs ranged from $8,537 for melanoma to $190,305 for acute myeloid leukemia. Continuing care costs ranged from $2,603 for prostate cancer to $28,525 for myeloma. For end-of-life care, costs ranged from $74,227 for prostate cancer to $249,125 for acute myeloid leukemia. Costs are highest in the last year of life, followed by the initial phase, with considerable variation by cancer site and phase of treatment (see Table 3).

Table 3:

Average Patient Cancer Costs for Medical Services

Cancer Type	Initial care ($)	Continuing care ($)	Last year of life ($)
Acute Myeloid Leukemia	190,305.00	21,758.10	249,124.70
Brain	139,813.80	17,385.60	176,354.90
Pancreas	108,165.70	18,426.70	125,030.80
Esophagus	89,947.20	9,785.90	120,033.80
Lung: Small Cell Carcinoma	85,366.60	14,783.00	118,055.80

Ovary	79,120.30	14,158.40	112,017.60
Stomach	79,120.30	7,079.20	122,011.80
Myeloma	77,038.10	28,524.90	123,365.10
Hodgkin Lymphoma	75,372.50	9,785.90	128,986.80
Non-Hodgkin Lymphoma	75,164.20	12,805.00	144,706.80
Lung	68,293.30	12,388.60	110,247.80
Lung: Non-small Cell Carcinoma	67,148.10	12,284.50	109,102.70
Colorectal	66,523.50	6,246.30	110,143.70
Liver	62,775.70	18,218.50	92,133.50
Cervix Uteri	58,715.60	3,956.00	97,026.40
Oral Cavity	58,715.60	5,934.00	110,039.60
Leukemia	47,263.90	12,700.90	169,588.00
All Sites	43,516.10	5,517.60	109,727.30
Kidney	41,121.70	8,536.70	95,985.40
Uterus	39,039.60	3,019.10	93,590.90
Breast	34,979.50	3,539.60	76,101.20
Chronic Myeloid Leukemia	34,875.40	13,950.20	122,428.20
Prostate	28,108.50	2,602.60	74,227.30
Bladder	26,442.80	6,350.40	95,985.40
Chronic Lymphocytic Leukemia	25,505.90	12,076.30	94,111.50
Thyroid	24,881.20	4,060.10	107,437.00
Melanoma	8,536.70	2,706.80	78,912.00

Notes. Average per patient annualized 2007-2013 cancer-attributable costs in 2020 US dollars for medical services related to cancer care by cancer site and phase of care (Mariotto et al., 2020)

While insurance can cover some expenses, the out-of-pocket (OOP) burden for patients remains significant. A systematic review found monthly OOP expenses ranged from $180 to $2,600, with an average of approximately $300 per month. Costs varied by cancer type: pediatric cancers averaged $764/month, hematological cancers $344/month, all cancers combined $242/month, breast cancer $197/month, and head and neck cancer $87/month (Iragorri et al., 2021).

The financial burden of cancer treatment can lead to financial toxicity, a term describing the harmful impact of treatment costs on quality of life, including financial burden and distress. Symptoms may include reduced spending on food, clothing, or leisurely activities; borrowing money or refinancing; skipping or not refilling medications; increased anxiety, stress, or depression (Hussaini et al., 2022). Research uses several related terms including medical financial hardship, financial distress, financial stress, financial hardship, financial burden, economic burden, and economic hardship to describe this situation.

The prevalence of financial toxicity among cancer patients is notably high. In a longitudinal study using nationally representative data of individuals aged 50 and older (Gilligan et al., 2018) estimated that among 9.5 million newly diagnosed cancer patients, a substantial portion experienced financial toxicity: by year two, 42.4% had depleted their entire life's assets. In another study of inpatients undergoing gynecologic cancer resections, financial toxicity was defined as health expenditures exceeding 40% of post-subsistence income. Approximately 52.8% of uninsured patients and 15.4% of insured patients met this threshold (Ng et al., 2022).

A systematic review highlighted a wide range of factors associated with financial toxicity among cancer survivors. Employment-related challenges, such as unemployment, reduced hours, or impaired ability to work, were consistently linked to greater risk. Socio-demographic characteristics—including younger age, non-white race, unmarried status, lower educational attainment, dependent care responsibilities, residence in non-metropolitan areas, and lower income or socioeconomic status—were also identified as risk factors. Additionally, financial toxicity was associated with higher household

expenses, personal debt, limited insurance coverage, greater illness severity, active treatment, and poorer physical functioning or quality of life (Mols et al., 2020).

Importantly, the financial burden of cancer is not limited to medical related expenses but includes employment changes. In one study, up to 94% of caregivers reported some level of work disruption, with a median annual income loss of 20% associated with cancer-related work changes (Bona et al., 2014). A nationally representative prospective study found that employment probability for people reporting a cancer diagnosis decreased by 9 percentage points over three years. During this period, survivors' labor market earnings dropped by up to 40%, while family income declined by 20% (Zajacova et al., 2015). Another study found that people undergoing cancer treatment missed 22.3 more workdays per year than those without any cancer treatment (Finkelstein et al., 2009).

A retrospective cross-sectional survey by Evans (2023) of caregivers of children with cancer found that financial toxicity (as measured by the COST score) was reported by 81% of low-, 68% of middle-, and 44% of high-income caregivers ($p < .001$). Overall, 58% of caregivers reported work disruptions (parent quitting a job, being laid off, taking leave), with middle-income caregivers most affected (79%) compared to low- (60%) and high-income caregivers (53%). In terms of income loss, 62% of caregivers reported less than 10% income loss, 21% reported 11–40%, and 17% reported more than 40%. Significant income loss (>40%) was more common in the low-income group (27%) but did not reach statistical significance (low 27% vs. middle 14% vs. high 12%, $p = .30$).

Given these financial hardships, families may be forced to reduce spending on essential needs such as food. Prior research suggests these financial strains increase the risk of food insecurity among cancer patients. For example, a prospective cohort study on pediatric patients by (Bona et al., 2016) found that 56% of parents experienced work disruptions due to their child's illness. Among these caregivers, 15% quit or were laid off, while 37% reduced hours or took unpaid leave. Low-income families lost a median of 49% of income, significantly more than higher-income families (6%, $p = .02$). Overall, material hardship (including food, housing, and energy) increased from 20% to 29% six months post-diagnosis, with higher frequencies of experiencing one, two, or all three hardships.

Interestingly, families newly developing new material hardship at six months were more likely to have had higher baseline incomes (p = .04).

In a retrospective study of adults asked about food insecurity before and after treatment, 10% became newly food insecure while 26% were persistently food insecure (McDougall et al., 2020). Newly food-insecure survivors were more likely to have $1,000–$9,999 in debt (OR 2.69; 95% CI, 1.08–6.71), while persistently food-insecure survivors were more likely to have debts ≥$10,000 (OR 2.07; 95% CI, 1.16–3.68). In a cross sectional study using national data, medical financial hardship (including material hardship- having problems paying or being unable to pay medical bills, psychological hardship- being very worried about medical bills and behavioral hardship- delaying medical care due to cost) was significantly associated with increased odds of food insecurity (Hallgren E. et al., 2023).

2.3.6 Non-Financial Contributors/Physical Hardship in Treatment

An under-explored area in cancer and food insecurity research is the role of non-financial contributors. As discussed, cancer and its treatment can cause symptoms and side effects that disrupt daily life, potentially limiting a person's ability to shop for or prepare food. This could lead to inadequate intake. For example, a study of adults aged 60 and older found that most participants faced physical access challenges (difficulty shopping for groceries, difficulty carrying groceries home, or difficulty preparing meals) (25%) rather than economic barriers (4.4%) to food (Vaudin et al., 2022). Some patients rely on caregivers for food-related tasks, but many older adults live alone— 27% of adults ages 60 and older in the United States (Cohn & Passel, 2020). Transportation is also a barrier to food access in the literature (Burns et al., 2011), and living in food deserts may further restrict access.

Research in this area is limited, as the standard USDA measure focuses solely on the financial domain of food access.

2.3.7 Implications of Food Insecurity in Cancer Care

Since nutrition is critical during cancer care, addressing food insecurity is essential for a population already facing substantial food-related challenges. While malnutrition outcomes have been

better studied in cancer care, less is known about the specific effects of food insecurity during treatment.

In a retrospective cross-sectional study, cancer survivors who were newly or persistently food insecure had significantly greater odds of delaying or forgoing medical care and of changing prescription medication regimens. Notably, newly food-insecure cancer survivors consistently had the highest probability of forgoing, delaying, or altering all types of care, with the largest disparity observed for mental health services (McDougall et al., 2020).

A single-center prospective study of patients undergoing hematopoietic stem cell transplantation found that those with food insecurity were more likely to develop malnutrition during treatment (70% vs. 45.1%, $p = 0.034$) and to require total parenteral nutrition (65% vs. 34.2%, $p = 0.013$) compared to food-secure patients. Food-insecure patients were also significantly more likely to screen positive for depression (40% vs. 10.4%, $p = 0.002$) and financial toxicity (75% vs. 25%, $p < 0.001$). However, no significant differences were observed in survival or other secondary outcomes (Bergens et al., 2025).

County-level analyses have shown disparities in surgical outcomes. Patients living in high–food-insecurity counties who underwent surgery for hepatopancreatic biliary cancers had lower odds of achieving optimal postoperative outcomes and higher mortality at 1, 3, and 5 years post-surgery (Chinaemelum et al., 2023). Similarly, colorectal cancer patients in high–food-insecurity areas had higher odds of non-elective surgery, extended hospital stays, readmissions, postoperative complications, and increased short- and long-term mortality (Azap et al., 2024).

Neighborhood-level food access also plays an important role. Living in food deserts has been linked to increased readmission rates after esophagectomy (Phillips et al., 2023), higher risk of endometrial cancer recurrence (Gordon et al., 2018), and worse survival outcomes for gynecologic cancers, including endometrial, ovarian, and cervical cancers (Lugo Santiago et al., 2024).

Data from the National Health and Nutrition Examination Survey (NHANES 1999–2018) examined the impact of food insecurity on mortality risk among U.S. cancer survivors. Participants

aged ≥ 20 years with a history of cancer who completed the Adult Food Security Survey Module showed that food insecurity was associated with a higher risk of cancer-specific mortality, even after adjusting for socioeconomic and health factors (Hong et al., 2024). However, a recent systematic review and meta-analysis examining cohort studies (not limited to cancer populations) found that while food insecurity was associated with increased all-cause and cardiovascular-related mortality, it did not show a statistically significant link to cancer-specific mortality (Jalili et al., 2025). The authors noted that many included studies did not adequately adjust for critical confounders such as cancer stage, treatment adherence, and nutritional status, all of which can significantly influence survival outcomes in cancer patients.

2.3.8 Addressing Food Insecurity At Cancer Diagnosis and During Cancer Survivorship

The need for adequate nutrition during cancer treatment and the potential consequences of food insecurity for cancer patients places an importance on preventing food insecurity prior to diagnosis and addressing food insecurity during diagnosis. Further untangling these mechanisms can help understand causes that can be addressed with interventions. The deliverables for this thesis hope to provide more insight into predictors for food insecurity at diagnosis as well as mechanisms to food insecurity after a diagnosis.

2.4 Study Rationale, Goals, and Research Questions

2.4.1 Rational

Advancing understanding of food insecurity among cancer patients requires both localized and comprehensive approaches. A quantitative study provides context-specific data on prevalence and predictors within one healthcare setting, while a systematic review synthesizes broader evidence on the mechanisms linking cancer and its treatment to food insecurity. Together, these complementary studies offer a more complete perspective than either approach could provide alone.

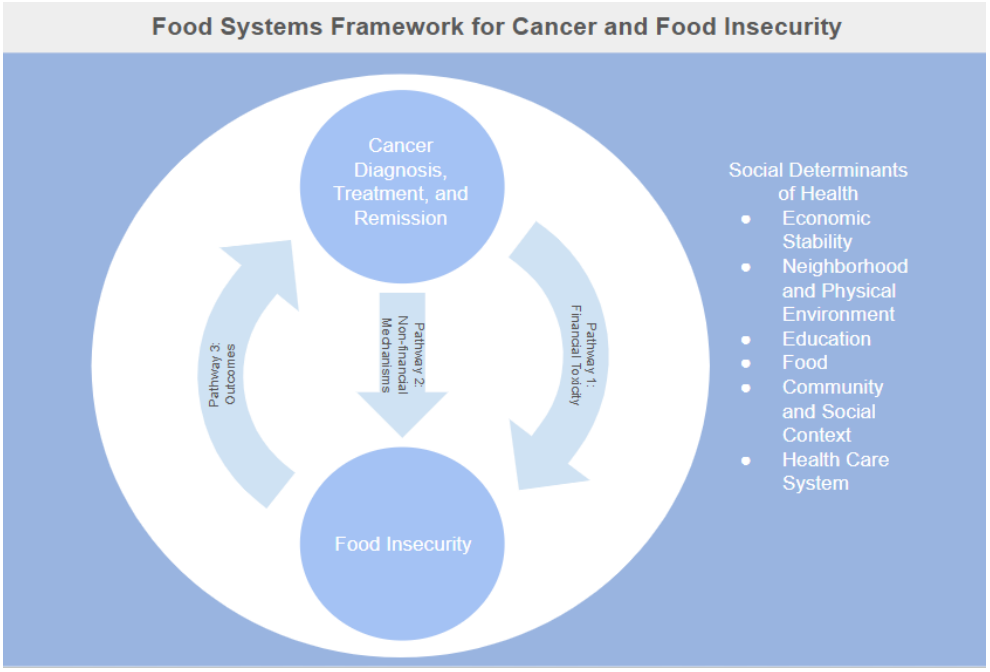
Deliverable 1 is a systematic literature review examining both the financial and non-financial mechanisms contributing to food insecurity among cancer patients. While financial hardship has been documented, non-financial factors remain far less studied. This review seeks to address that gap by

synthesizing evidence on multiple pathways through which cancer and its treatment may influence FI, with attention to the unique barriers faced by vulnerable groups. Because existing FI measurement tools primarily capture financial access, this review also highlights opportunities to expand and improve measurement approaches in oncology settings

This work is guided by a proposed conceptual framework (Figure 1) that adopts a food systems–based perspective. The framework includes two primary mechanisms: (1) the Financial Mechanisms Pathway and (2) the Non-Financial Mechanisms Pathway, both of which affect the quantity and quality of food households are able to obtain. A third pathway—(3) the Outcomes Pathway—illustrates how FI may in turn influence cancer care and outcomes, such as treatment adherence, disease progression, remission, or recurrence. While outcomes are not the focus of this review, they represent an important area for future research. The entire framework is situated within the Social Determinants of Health (SDOH), acknowledging that broader social and structural conditions shape all aspects of FI and cancer care.

Figure 1:

Food Systems Framework for Cancer and Food Insecurity



Deliverable 2 examines the prevalence and predictors of food insecurity among newly diagnosed cancer patients at the University of Vermont Medical Center (UVMMC), an academic medical facility serving a predominantly rural and older population. Unlike many prior studies that focus on urban areas, safety-net settings, or long-term survivors, this analysis from a predominantly rural state captures FI shortly after diagnosis, providing insight into both baseline prevalence and early vulnerabilities. These localized data can help refine screening practices and identify subgroups at heightened risk within an otherwise well-resourced care setting

2.4.2 Goals, Objectives, and Questions

Deliverable 1 (Chapter 3):

- Goal: Synthesize evidence on mechanisms linking cancer and its treatment to food insecurity.
- Objectives:
    - Conduct a systematic review of financial and non-financial mechanisms.
    - Summarize existing evidence to inform the proposed conceptual framework.
- Research Question: How does a cancer diagnosis influence food insecurity via multiple mechanisms?
    - Pathway 1: How does a cancer diagnosis influence food insecurity via financial mechanisms?
    - Pathway 2: How does a cancer diagnosis influence food insecurity via non-financial mechanisms?

Deliverable 2 (Chapter 2)

- Goal: Assess prevalence and demographic predictors of food insecurity among cancer patients at an academic medical center in a predominantly rural state.
- Objectives:
    - Measure food insecurity prevalence six weeks post-diagnosis.

    - Identify demographic and clinical factors associated with food insecurity.
- Research Question: What are the demographic predictors and prevalence of food insecurity among cancer patients six weeks after diagnosis at UVMMC?

CHAPTER 3: MECHANISMS TO FOOD INSECURITY FOLLOWING A CANCER DIAGNOSIS: A SYSTEMATIC REVIEW AND IMPLICATIONS FOR MEASUREMENT

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Sending for hopeful publication at: Nutrition Reviews

Abstract:
Food insecurity (FI) is an emerging concern in cancer care that may arise through multiple mechanisms across the cancer care continuum. Financial challenges—such as increased medical expenses and employment disruptions—are well documented, but FI may also arise from non-financial factors, including physical limitations related to treatment, transportation barriers, residence in food deserts, and social isolation affecting food procurement and meal preparation. This systematic review applied a food systems lens to identify and characterize both financial and non-financial mechanisms contributing to FI following a cancer diagnosis. A comprehensive search of Web of Science, Ovid MEDLINE, EMBASE, CABI, and CINAHL identified U.S.-based studies of individuals with active or a history of cancer, published through November 2024. Twenty-one studies met inclusion criteria, screened independently by two reviewers. FI prevalence ranged from 6.2% to 72.7%. Most studies (20/21) examined financial mechanisms, documenting income loss, work disruptions, increased medical expenses, and material hardship, particularly among younger adults, lower-income individuals, and racially/ethnically minoritized populations. Non-financial contributors were rarely measured explicitly (1/21), though nine studies measured items that could potentially influence food access. Only six studies examined changes in FI longitudinally, limiting causal inference. These gaps highlight that current screening practices, which focus largely on financial access, may underestimate the needs of cancer patients. Findings underscore the importance of integrating a broader understanding of FI into both research and clinical practice to improve nutritional care and health outcomes in this population.

Introduction:

The U.S. Department of Agriculture Economic Research Service defines food insecurity (FI) as "difficulty providing enough food for all household members due to insufficient resources at some point during the year" (1). This definition primarily emphasizes financial barriers to food access, which are further corroborated through their measurement tool which focuses on having enough money for food access. In contrast, other multidimensional FI definitions also consider non-financial factors. For example, the Committee on World Food Security defines food and nutrition security as existing "when all people, at all times, have physical, social, and economic access to food that is safe and consumed in sufficient quantity and quality to meet their dietary needs and food preferences, supported by an environment of adequate sanitation, health services, and care, enabling a healthy and active life." This definition comprises four domains: (1) availability—the amount of food in a country or region through domestic production, imports, food stocks, and food aid; (2) access—the ability to obtain appropriate foods through physical, economic, and social means; (3) utilization—the use of food through adequate diet, clean water, sanitation, and health care; and (4) stability—consistent access to adequate food at all times, without risk of disruption due to economic, climatic, or political factors (2). This definition is widely used in both academic literature, and in international measurements of FI, in order to more fully capture the suite of reasons that FI may occur.

An emerging area of research, especially in the United States, explores the extent to which cancer patients may be at increased risk for FI both at and after diagnosis and for both financial and non-financial reasons. FI is associated with cancer prevalence (i.e., FI at the time of diagnosis) through its association with poor diet quality (3–7), reduced screening (8–10), barriers to healthcare access (11–14), and broader socioeconomic disadvantage. Conversely, cancer diagnosis and treatment may exacerbate FI through both financial and non-financial pathways, especially in the United States where healthcare structure and costs are significantly different than many other high-income countries. Unlike most high-income OECD countries, the U.S. lacks universal health coverage and

instead relies on a fragmented mix of public programs, private insurance, and out-of-pocket spending (15), contributing to higher healthcare costs (16) which may place greater risk at unmet basic needs such as food.

Cancer diagnosis and treatment place substantial financial strain on households through both direct and indirect costs. Medical expenses --including diagnostic tests, doctor visits, treatments, procedures, imaging, hospital stays, and home care, and specialist consultations—are considerable, with out-of-pocket expenses ranging from $180 to $2,600 per month, with an average of approximately $300 per month (17). Beyond medical bills, families often face additional financial burdens such as transportation expenses, childcare needs, and lost wages. In one study, 58% of caregivers reported work disruptions (quitting a job, being laid off, taking leave) with 21% losing 11–40% of their income and 17% losing more than 40% (18). The financial burden of cancer and its treatment can lead to financial toxicity (FT), defined as the harmful impact of treatment costs on quality of life (19). In one study of caregivers of children with cancer, financial toxicity was reported by 81% of low-, 68% of middle-, and 44% of high-income caregivers ($p < .001$) (18). These hardships can force families to reduce spending on essentials such as food (20).

Non-financial mechanisms contributing to FI post-diagnosis are less understood but could include physical limitations related to illness or treatment, transportation challenges, residence in food deserts, and social isolation. In a nationally representative study assessing physical FI, 25.0% of older adults (≥60 years) had physical difficulty accessing food but were not living in economically insecure households (21). Physical access barriers may be particularly concerning for patients who live alone, a group that includes about 27% of U.S. adults aged 60 and older (22).

The consequences of FI in cancer care are substantial, as unmet food and nutritional needs are documented to worsen health outcomes. FI is linked to delays or forgoing care, alterations to medication regimens—particularly in those newly experiencing FI (23)--increased risk of financial toxicity (24), and greater likelihood of malnutrition (24). Malnutrition in cancer typically arises from a

combination of inadequate intake and disease-specific metabolic disturbances (25) and is associated with treatment-related toxicity (26,27), treatment discontinuation(28), ER visits (26), hospitalizations (26,28), and mortality (27,29–31). An estimated 10–20% of cancer-related deaths are attributable to malnutrition rather than the cancer itself (32). These outcomes highlight the importance of addressing nutrition-related challenges, particularly FI, within cancer care, and understanding the mechanisms driving FI after diagnosis to inform prevention strategies.

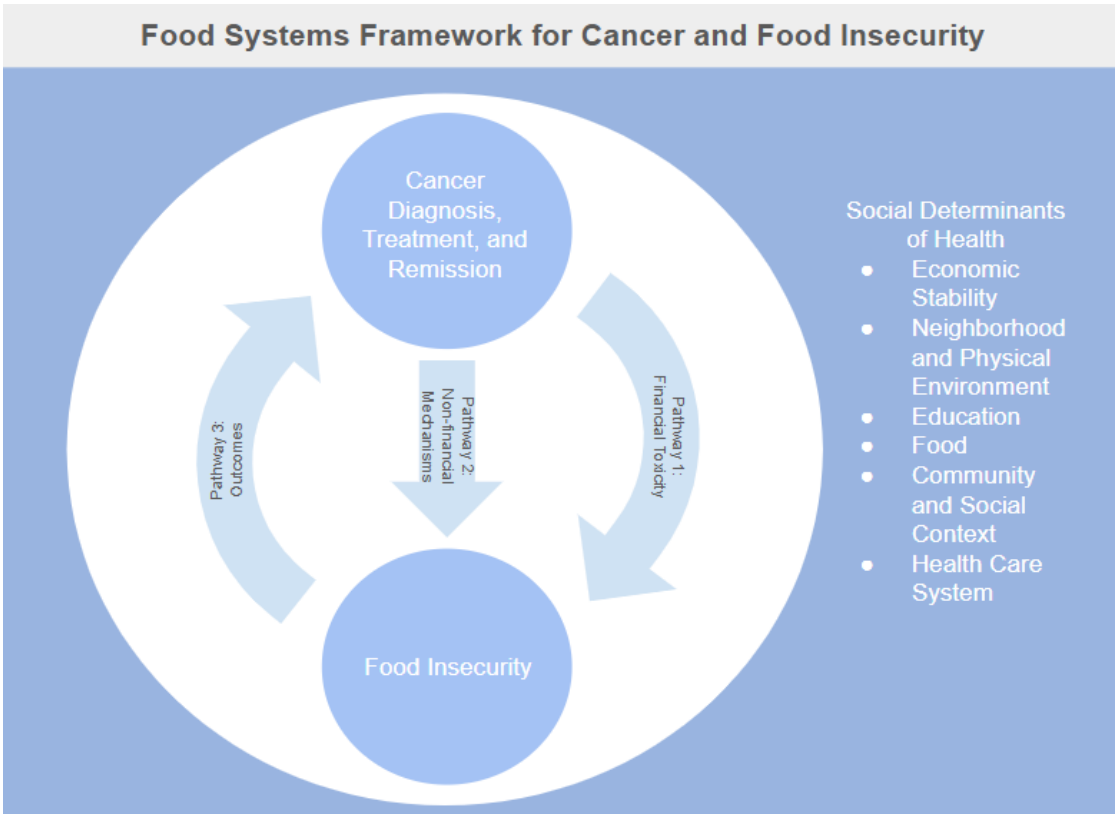
This review aims to characterize the existing literature on FI in cancer patients by using a food systems approach that accounts for both the financial and non-financial mechanisms. Financial mechanisms leading to FI (falling under the FAO's access domain) may include medical financial hardship and work disruptions. Non-financial pathways can extend across all four FAO food security domains—for example: availability (disruption of home food production during treatment); access (physical limitations procuring food, transportation barriers, residence in a food desert); utilization (limitations in food preparation or self-feeding, inadequate home food-preparation equipment, lack of safe water and sanitation, limited diet diversity); and stability (any time of the month of year when running low on food which could correspond with treatment type and timeline, changes in FI status over time during care, and disruptions such as COVID-19).

We simplified these indicators into a completely original proposed framework (Figure 1) that adopts a broader food systems-based perspective on how cancer and its treatment may influence FI. This framework included two primary mechanisms: (1) the Financial Mechanisms Pathway and (2) the Non-Financial Mechanisms Pathway, both of which can affect the quantity and quality of food households are able to obtain. In turn, FI may influence cancer care and outcomes through a third pathway—(3) the Outcomes Pathway—which was not assessed within the scope of this review (but is a relevant area of future research). This may include impacts on treatment adherence, disease progression, remission, or recurrence. The entire framework was situated within the context of the Social Determinants of Health (SDOH), recognizing that these broader social and structural factors

influence all aspects of the model. Social determinants of health (SDOH) are non-medical factors, such as socioeconomic status and geographic location, that influence health outcomes (33), with adverse SDOH linked to poorer health outcomes (34).

Figure 1:

Food Systems Framework for Cancer and Food Insecurity



The goal of this review was to synthesize evidence on mechanisms linking cancer and its treatment to FI. Specifically, our objectives were to: (1) conduct a systematic review of both financial and non-financial mechanisms, (2) summarize existing evidence to inform the proposed conceptual framework, and (3) to characterize the evidence about populations at greatest risk for FI. Our guiding research question was: How does cancer diagnosis and treatment influence FI through multiple pathways?

Methods:

A protocol for this systematic review was registered with PROSPERO September 1, 2024 (35). A comprehensive search was conducted on November 21-22, 2024, across Web of Science, Ovid MEDLINE, EMBASE, CABI, and CINAHL. The complete list of search terms is provided in Supplemental Materials (SM1). Search terms were limited to food insecurity–related concepts (e.g., food insecurity, food desert, hunger). While the FAO framework encompasses a broad range of potential indicators across availability, access, utilization, and stability, the intention of this search was to capture studies in which authors explicitly conceptualized their work as food insecurity–related, rather than all studies that could theoretically align with these domains. All retrieved records were imported into Covidence systematic review software (36) for screening and duplicate entries were automatically removed.

Screening and Eligibility

Two reviewers independently screened titles and abstracts against predefined inclusion and exclusion criteria. Discrepancies were resolved through discussion until consensus was reached.

Studies were included if they met all the following criteria: the population consisted of individuals with active cancer or a history of cancer, the study addressed an aspect of FI and either a financial or non-financial mechanism, the study was conducted in the United States, and it was published in English in a peer-reviewed journal. Studies were included from database inception through 2024, as food insecurity in oncology is a relatively new area of research and nearly all published studies have emerged within the past decade.

Studies were excluded if they examined only social determinants of health (SDOH) or health-related quality of life without explicitly addressing both cancer and FI.

Full-Text Review

Full-text review was conducted by the lead author, with input from a third reviewer (the senior and last author), to determine final eligibility. A common reason for exclusion at this stage was studies reporting prevalence or demographic correlates of FI without examining the mechanisms—financial or non-financial—driving FI.

Data Extraction

Full-text articles had data extracted on the following elements: population and setting characteristics (e.g., cancer type, stage, treatment); FI measurement tools; timing of FI assessment (e.g., at diagnosis, during treatment, post-treatment), FI prevalence; evidence of financial and non-financial mechanisms contributing to FI; major findings and subgroup differences; and author-reported limitations. Information on underserved or low-resource settings was extracted to contextualize findings. Federally qualified health centers (FQHCs) and safety-net clinics primarily serve patients from low-income communities, which may inflate FI estimates compared with higher-resource settings. A complete list of extracted elements is available in Supplemental Materials (SM2).

Quality Appraisal

Study quality and risk of bias were assessed using a modified version of the Academy of Nutrition and Dietetics Quality Criteria Checklist (37). The checklist was adapted by selecting and updated relevant questions from the original AND tool to ensure applicability for cross-sectional research in this review (see SM3). Two reviewers conducted quality assessments independently, with disagreements adjudicated by a third reviewer (the senior and last author). Although no studies were excluded based on quality or bias, results were documented and included in supplementary materials (SM4).

Results:

Study Selection

As shown in Figure 2, The database search yielded 3,139 studies after 1553 duplicates were removed. Following title and abstract screening, 71 articles were retained for full-text review. Of these, 50 studies were excluded for one or more of the following reasons: full text not available (abstract only); outcomes unrelated to FI mechanisms (e.g., treatment outcomes only); irrelevant intervention (e.g., COVID-19); non-U.S. setting without U.S.-specific data; or protocol-only publications. In total, 21 studies met the inclusion criteria and were extracted for synthesis (18,20,21,23,38–54).

Figure 2. Flow Diagram of the Literature Search Process

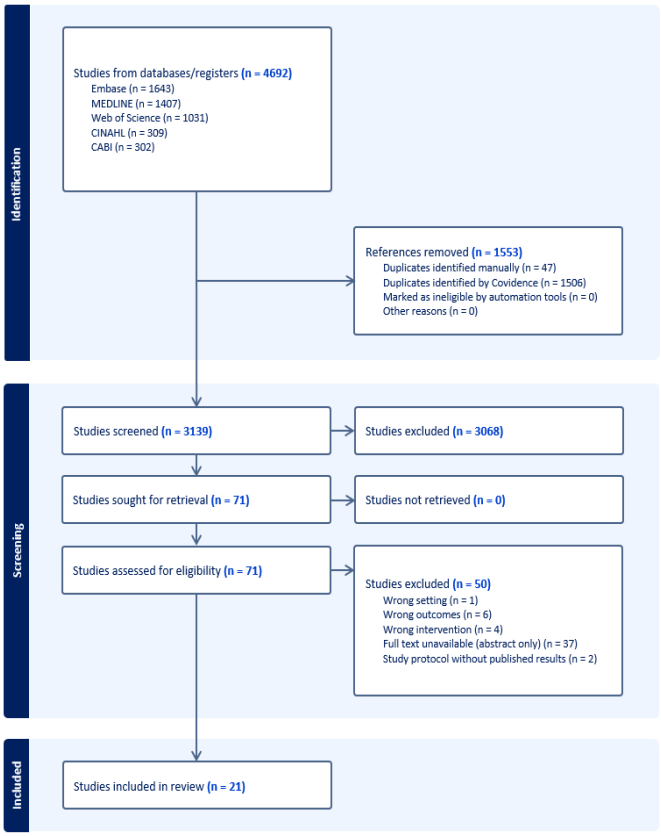
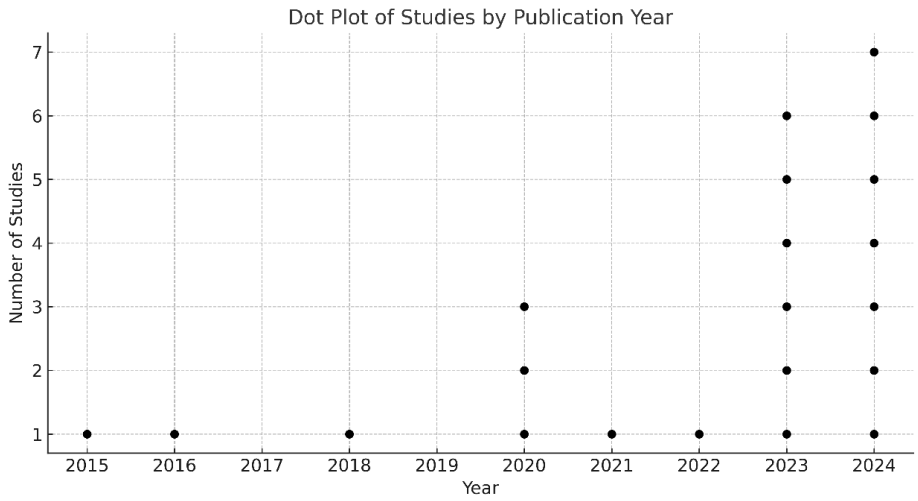


Figure 2: *A flow diagram of study selection for a systematic review of mechanisms to food insecurity among cancer patients and survivors in the United States.*

Figure 3:

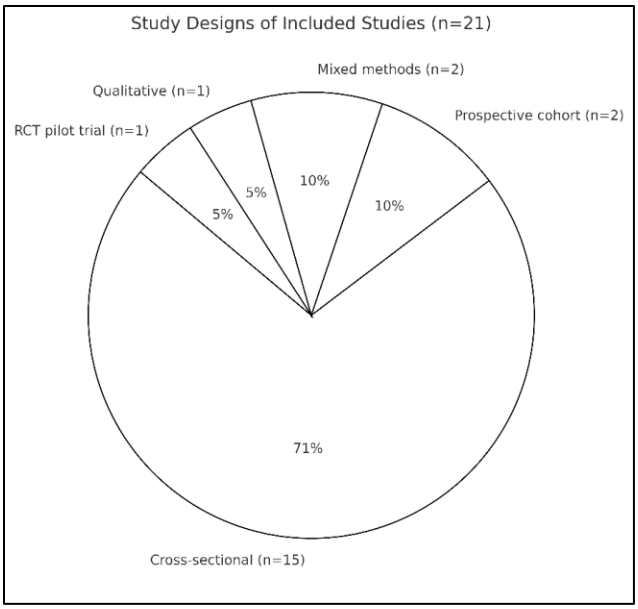
Dot Plot of Studies by Publication Year



Notes. Each dot represents one study (n = 21). Most included studies were published since 2020, highlighting the emerging nature of research on food insecurity and cancer.

Figure 4:

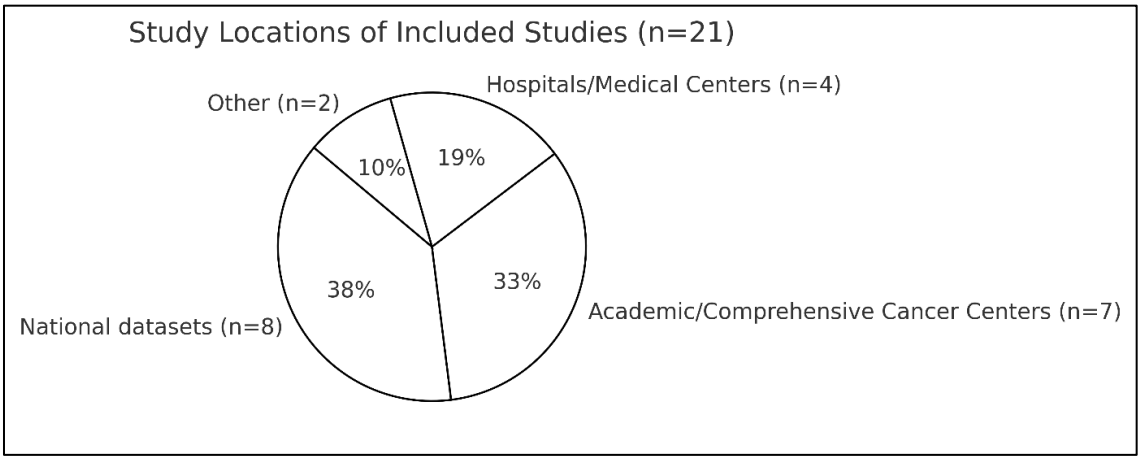
Study Designs of Included Studies



Notes. Most studies were cross-sectional (four of which were retrospective cross-sectional), with fewer using cohort, mixed-methods, qualitative, or randomized trial designs.

Figure 5:

Study Location of Included Studies



Notes. Most studies were conducted using national datasets, followed by academic/comprehensive cancer centers, hospitals/medical centers, and other settings. Academic/Comprehensive Cancer Centers included Dana-Farber Cancer Institute, Stephenson Cancer Center, UCSF Benioff Children's Hospitals, University of New Mexico Comprehensive Cancer Center, MD Anderson Cancer Center, and a multi-site study across six U.S. pediatric cancer centers. Hospitals/Medical Centers included New York–Presbyterian medical centers, Lyndon B. Johnson Hospital Oncology Clinic, and two community cancer clinics in eastern North Carolina. Other settings included a medical center food pantry (University Medical Center New Orleans) and the New Mexico statewide tumor registry. Categorization of settings was occasionally nuanced, as some institutions could be considered both hospital-based and academic.

Study Characteristics and Population

Table 4 shows a summary of included studies (n=21). As shown in Figure 3, most studies (n=13) were published since 2023. As shown in Figure 4, most studies (n=15) were cross-sectional. As shown in Figure 5, most studies (n=8) were done nationally.

Most studies reported a diverse mix of cancer and treatment type within their samples, but some studies (n=8) focused on certain cancer types and/or treatments (population specifics are in Table 4)(20,23,39,40,43,44,47,48). Most studies included participants from a range of racial and ethnic backgrounds, though most samples were predominantly White and English-speaking. Four studies specifically focused on particular racial or ethnic groups (38,48–50). Most studies focused on adults with cancer (n=15), with others focusing on pediatric patients or caregivers of pediatric

patients (n=6) (18,20,39,40,45,50). Income was stratified in many studies, though cutoff points for what was considered low-income differed. The income profile of study participants is included in Table 4.

Food Insecurity Measures

Most studies (17 of 21) measured FI using the USDA Food Security Tool (55) or adaptations such as NHIS, NHANES, and Hunger Vital Sign questions (18,20,21,23,39–45,47,48,51–54). Six studies used non-standard approaches, including CARES-SF, ENRICh FT, and qualitative interviews(21,38,46,47,49,56). In Shi 2023, which employed a non-standard approach, patients were directly asked how cancer and its treatment affected their ability to pay for food, explicitly linking FI to the cancer experience rather than assessing FI in general (49). Four studies used multiple measures of FI (21,47,49,56), and one did not specify (56). FI was almost always measured financially; only one study used ADL items to capture non-financial aspects (21).

Financial and Non-Financial Measures

A vast majority of studies (20 of 21) examined financial mechanisms of FI, though the specific measures were highly heterogeneous and are elaborated on later. Non-financial mechanisms were rarely assessed; only one study measured them explicitly (21), while nine others captured items that could potentially influence food access (18,38,39,43,46,48,49,53,56).

Bias Quality Assessment

. Of the longitudinal studies, four of five (80%) received an overall positive (+) quality rating (18,23, 39,45). Among the cross-sectional studies, 10 of 15 (67%) were rated as + quality rating (21,41,42,44, 46, 48,49,51–54). Of the qualitative studies, one of three (33%) received a + quality rating (49). Mixed-method studies were double-counted in both the qualitative and quantitative sections for consistency in how results are presented in this review. The most frequent assessment questions studies did not receive a strong score were for potential participant selection bias, reliance

on non-validated survey tools, and limitations in statistical analysis—either lack of statistical analysis or lack of multivariate adjustment for confounding variables. No consistent pattern emerged in the reasons for lower scores across study designs, which may in part reflect the small number of studies in each category.

Table 4:

Summary of Included Studies

Citation	Study Design	Location	Sample Size (N)	Population Summary	Underserved Context; Income Profile*	Food Insecurity Measurement Tool	Bias/ Quality Score
Anderson-Buettner, 2024(38)	Qualitative	Stephenson Cancer Center, Oklahoma	7 patients and 4 providers	Native American cancer patients (age 18+) and cancer care providers; mixed diagnoses and treatment stages	I/T/U eligibility is tribal, not income-based, though it primarily serves low-income individuals; income data not reported	FI identified through interviews; no formal screening tool used	N
Aziz-Bose, 2024(39)	Prospective cohort	6 U.S. pediatric cancer centers	287	Pediatric patients with newly diagnosed leukemia undergoing chemotherapy; racially and ethnically diverse sample; multiple languages	Unknown due to unspecified pediatric cancer centers; 37% <185% FPL and mean household income for whole sample $116,800	USDA, 2-item	+
Bona, 2015 (40)	Cross-sectional	Dana-Farber Cancer Institute in Boston, Massachusetts	45	Families with a child post-hematopoietic stem cell transplantation; mostly White and entirely English speaking sample	Not an underserved setting; 40% had household income ≤200% FPL	USDA, six-Item	N
Bona, 2016 (20)	Prospective cohort	Dana-Farber Cancer Institute in Boston, Massachusetts	99	Families of children newly diagnosed with cancer (hematologic, solid tumors, and brain tumors) receiving chemotherapy; mostly White and entirely English speaking sample	Not an underserved setting; 22% reported income ≤200% FPL and baseline median income: $99,544	USDA, six-Item	N
Evans, 2023 (18)	Retrospective cross-sectional	UCSF Benioff Children's Hospitals in	156 caregivers	Caregivers of children with cancer receiving chemotherapy or radiation; cancer type and	Not an underserved setting; 32% <200% FPL	Hunger Vital Sign screener	+

		San Francisco and Oakland California		stage not specified; racially and ethnically diverse sample; English or Spanish speaking			
Garcia, 2018 (41)	Cross-sectional	National; data from NHIS 2011-2014 and MEPS 2013-2015	14,879 (those with cancer history are ~25% of this)	Adults aged 50 and older with specific chronic health conditions; demographics and cancer specific information for the cancer population not reported	Not an underserved setting; of those FS 35.1% <200% FPL and of those FI 71.8% <200% FPL (whole sample/not cancer specific)	NHIS, 10-items	+
Hallgren, 2023 (42)	Cross-sectional	National; data from NHIS 2020	4,130 Survivors vs. 27,438 non-cancer adults (NHIS total n=31,568)	Cancer survivors with different types of cancers and descriptive comparisons made to adults without cancer; stage and treatment type unknown	Not an underserved setting; 26% ≤100–199% FPL	NHIS, 10-items	+
Hao, 2024 (43)	Retrospective cross-sectional	Two cancer clinics in eastern North Carolina	152	Patients with a gastrointestinal cancer diagnosis receiving care; treatment type unspecified; AJCC analytic stage: Stage 0 0.9%, Stage I 25%, Stage II 20.5%, Stage III 25.9%, Stage IV 27.7%. Racially and ethnically diverse sample.	Healthcare entity not specified; 19.9% below poverty line and median household income $38,320	Hunger Vital Sign	N
Kobritz, 2024 (44)	Cross-sectional	National; data from NHIS 2019 to 2021	642 with CRC and 642 controls (without CRC)	Colorectal cancer survivors (and controls with no cancer history), both early onset and average onset colorectal cancer; cancer stage at diagnosis and treatment not specified	Not an underserved setting; income data not reported	USDA tool, unspecified	+
Lin, 2024 (45)	Retrospective cross-sectional	UCSF Benioff Children's Hospitals in San Francisco	156 caregivers	Caregivers of children with cancer receiving treatment; variety of cancers; variety of treatments (chemotherapy,	Not an underserved setting; 52% low-to-middle income (<200%-400% FPL)	Hunger Vital Sign	+

		and Oakland California		radiation, surgery); racially and ethnically diverse sample			
Luo, 2023 (46)	Cross-sectional	University Medical Center New Orleans (UMC) food pantry, New Orleans, Louisiana	400	Individuals living with cancer and qualifying for pantry services (income <130% of the federal poverty level); diagnosis and treatment information not reported	Underserved setting (food pantry); all participants had income <130% FPL	One item from the adapted CARES-SF that asked about difficulty affording food	N
McDougall, 2024 (47)	RCT Pilot Trial	University of New Mexico Comprehensive Cancer Center, Albuquerque, New Mexico	14 completed the trial	Adult patients diagnosed within the past 24 months with stage I–III breast or gynecological cancers and who completed initial cancer-directed therapy; specific treatment types (e.g., chemo, radiation) were not reported; all were food insecure at baseline	Not an underserved setting, but patients had to be food insecure to be included in the study; 70% of participants had annual income <$30,000	Hunger VitalSign for screening; follow-up used USDA indicators	N
McDougall, 2020 (23)	Retrospective cross-sectional	New Mexico (patients identified through the New Mexico Tumor Registry and recruited statewide	N = 394 participants (final analytic sample = 368 after exclusions)	Adults aged 21–64 with stage I–III breast, colorectal, or prostate cancer; 43% stage I, 40% stage II, 16% stage III. Most had surgery (88%); other treatments included chemo (40%), radiation (36%), hormone (29%), and biologic/immunotherapy (4%). Racially/ethnically diverse sample.	Not an underserved setting; income data not reported for full sample	Hunger Vital Sign	+
Rosenberg, 2024 (48)	Cross-sectional	Four New York-Presbyterian (NYP) medical	87	Adult patients with metastatic breast cancer; treatment type not specified. Racial/ethnic composition: 41% Non-Hispanic White, 28% Non-	Not an underserved setting; income data not reported	Single-item derived from the USDA	+

		centers in NYC (Manhattan, Brooklyn, and Queens)		Hispanic Black, 14% Hispanic/Latina, 10% Other/multiracial/unknown, and 7% Asian American or Pacific Islander.			
Shi, 2023 (49)	Mixed methods (qualitative cognitive interviews and cross-sectional survey)	Lyndon B. Johnson Hospital Oncology Clinic (LBJ) & University of Texas M.D. Anderson Cancer Center (MDA) Both in Houston, Texas	77 quantitative portion, 23 qualitative portion	Hispanic adults with cancer in active treatment or follow-up/surveillance; multiple types of cancer (breast, gastrointestinal, hematologic, lung, and others); most received chemotherapy; all had been diagnosed within 5 years with most being diagnosed more recent	60% of participants received care at a safety-net hospital (<150% FPL); 19%–96% <$35,000 across groups (insured English: 19%, un/underinsured English: 96%, un/underinsured Spanish: 52%)	One-item from the ENRICh FT tool In qualitative responses FI was identified as a subtheme for hardships	+
Valenzuela, 2023 (50)	Sequential mixed-methods (cross-sectional survey and semi-structured interviews)	Dana-Farber Cancer Institute in Boston, Massachusetts	60 parents completed the survey and 20 participated in interviews	Black and Hispanic parents of children with cancer; 6 weeks post-diagnosis to 1 year off therapy; multiple types of cancer (hematologic, solid tumor, brain tumor, stem cell transplant); 72% actively receiving treatment; treatment types not specified	Not an underserved setting; 41% were ≤100% of the FPL	Not specified-FI was measured as part of a 5-item HMH screening In qualitative responses, HMH was identified as a major theme	N
Valero-Elizondo, 2021 (51)	Cross-sectional	National; data from NHIS 2013–2018	141,826 (cancer only = 6,887,	US adults stratified into four groups: no ASCVD or cancer, ASCVD only, cancer only, and	Not an underserved setting; within the	NHIS, 10-items	+

			both ASCVD and cancer =971)	both ASCVD and cancer; multiple types of cancer (skin cancers, breast, cervix, and prostate most commonly reported); treatment type not reported	cancer group 22.1% were <200% FPL		
Vaudin, 2022 (21)	Cross-sectional	National; data from NHANES 2013–2018	4,820 total (26.9% of the sample had cancer)	U.S. adults aged ≥60 years; cancer type and treatment type unspecified	Not an underserved setting; 28.5% of full sample (not cancer specific) <185% FPL	NHANES; financial FI via HFSSM, non-financial FI via ADL items (shopping, carrying, preparing food).	+
Zheng, 2020a (52)	Cross-sectional	National; data from NHIS 2013-2017	11,911	U.S. adults with a self-reported history of cancer; multiple types of cancer (nonmelanoma skin cancer or skin cancer with unknown types were excluded; cancer stage and treatment phase not specified	Not an underserved setting; 26.5% <200% FPL for ages 18-64 and 22.7% <200% FPL for ages ≥65 years old	NHIS, 3-items	+
Zheng 2023 (53)	Cross-sectional	National; data from NHIS 2013 to 2018	22,941 children (812 with parental cancer history)	Children aged 5 to 17 with and without parental cancer history; cancer diagnosis and treatment not specified	Not an underserved setting; 46.1% vs. 42.6% with income <200% FPL (parental cancer vs. no cancer history	NHIS, 3-items	+
Zheng, 2020 (54)	Cross-sectional	National; data from NHIS 2013–2017	Cancer Survivors: 12,141 Non-Cancer Respondents: 143,664	Cancer survivors and those without cancer; multiple types of cancer (excluded those with nonmelanoma or unknown skin cancers); cancer stage and treatment type not reported	Not an underserved setting; % <200% FPL by age (survivor vs. no cancer): 18–39: 42.5% vs. 35.4%; 40–64: 23.6% vs. 24.2%; ≥65: 23% vs. 28.3%	NHIS, 3-items	+

**Underserved Context refers to a federally qualified healthcare center (FQHC), safety-net clinic, or setting specific to serving low-income individuals and families; to give a reference point for "Income Profile" 28.2% of the USA was <200% FPL in 2023 (57)*

Abbreviations: FI = Food Insecurity; FS= Food Secure; FPL = Federal Poverty Level; SNAP = Supplemental Nutrition Assistance Program; NHIS = National Health Interview Survey; NHANES = National Health and Nutrition Examination Survey; USDA = United States Department of Agriculture; RCT = Randomized Controlled Trial; "I/T/U" is abbreviated for Indian Health Service (IHS), a tribal health facility, or an IHS supported urban health program; HMH = Household Material Hardship

Notes: NHIS is nationally representative of the noninstitutionalized population which includes patients in long-term care facilities, those on active duty, those incarcerated, those living in homeless shelters or group homes, and US nationals living in foreign countries. They are also nationally representative of geography

Prevalence of Food Insecurity

Among the six studies that examined FI longitudinally (three retrospective cross-sectional (18,23,45), two prospective cohorts (20,39) and one RCT (47)(Table 5), all reported increases. One increase was not statistically significant (39) and two did not test significance (23,47). However, heterogeneity in how FI prevalence was reported limited comparability. For example, two studies reported household material hardship without isolating FI prevalence (18,45), and another presented FI indicators without giving an overall prevalence estimate (47). When averaging the remaining three studies by Aziz-Bose 2024, Bona 2016, and McDougall 2020, baseline FI was 31%, increasing to 37% at follow-up (6 or 12 months post-diagnosis)(20,23,39). McDougall 2020 provided detailed trajectories, reporting 58% persistently food secure, 10% newly food insecure, 26% persistently food insecure, and 3% whose FI resolved after diagnosis (23).

Among cross-sectional studies (excluding those that asked patients to recall FI before and after diagnosis, which are summarized above), the timing of FI assessment—at diagnosis, during treatment, or post-treatment—was often inconsistent or unstated (Table 6), making comparisons difficult. Reported prevalence ranged widely: the lowest was 6.2% among adults ≥65 years in a nationally representative NHIS study using the 3-item screener (54), while the highest was among uninsured or underinsured Spanish-speaking Hispanic adults in active treatment or surveillance. In that study, participants rated on a 0–10 scale how much cancer and its treatment affected their ability to pay for food, with an average score of 4 and 72.7% reporting some impact (measured with a one-item ENRICh tool) (49). Variation in measurement tools also complicated comparisons.

National data sets (n=8) consistently applied USDA-adapted FI measures but provided limited clarity on timing (21,41,42,44,51–54). Participants were asked whether they had ever been diagnosed with cancer, capturing both recent and long-past survivors; only 12-18.8% had

been diagnosed within the prior two years (42,52–54). However, of these studies, four (42,51,53,54) compared recent and long-term survivors and all found similar FI rates between groups. Within national studies, excluding those that combined FI with household material hardship, pooled survivors with other conditions, or reported only item-level measures, prevalence across national analyses ranged from 6.2% among survivors aged ≥65 to 27.0% among young adults aged 18–39 (54).

In mixed-methods studies with a quantitative component (49,50), prevalence findings are reported above with cross-sectional results. In the exclusively qualitative study (38), FI emerged as a treatment-related challenge through participant responses, but no formal screening tool or prevalence measure was used.

Table 5:

Studies Reporting Changes in Food Insecurity Over Time

Citation	Sample Notes	FI Measurement Tool	FI Measurement Timepoints	FI Change over Time
Aziz-Bose, 2024 (39)	Pediatric patients with newly diagnosed leukemia receiving treatment	USDA, 2-item	At diagnosis (T0) and again 6 months (T1) into treatment	**No significant change**: In a paired subgroup (n = 99), 53% were food insecure at T0 and 55% at T1 (McNemar's $p = 0.85$), indicating no statistically significant change in prevalence over time. There was turnover in status: 13 families became food secure, 15 became food insecure. Paired data and *p*-value obtained through direct communication with the study author. Changes in FI for the entire cohort (i.e., including families not eligible for SNAP) are not reported.
Bona, 2016 (20)	Families of children newly diagnosed with	USDA, six-Item	Baseline data collected after diagnosis (mean 22.9 days post-	**Increase** from 11% to 20% (no *p* value recorded); low-income families were significantly more likely

	cancer		diagnosis) and follow-up was collected 6 months later (mean of 234.9 days post-diagnosis)	to be FI at baseline (p= <0.001) and there was more of an increase with the higher income group (p=0.04)
Evans, 2023 (18)	Caregivers of children with cancer receiving treatment	Hunger Vital Sign	Caregivers were retrospectively asked to report HMH (which included FI) at diagnosis and the 12 months after diagnosis.	**Increase** in overall HMH from 36% to 52%, p=.001. Low Income: 67 to 84% (p=.046) Middle Income: 39 to 75% (p=.004) High Income: 8.8 to 18% (p=.041) Increases in HMH affected all income groups. FI specific change over time not isolated
Lin, 2024 (45)	Caregivers of children with cancer receiving treatment	Hunger Vital Sign	Caregivers were retrospectively asked to report HMH (which included FI) at diagnosis and the 12 months after diagnosis.	**Increase** in overall HMH is reported 36% to 52%, p=.001, but FI-specific change over time is not isolated
McDougall, 2020 (23)	Adults with breast, colorectal, or prostate cancer	Hunger Vital Sign for screening; follow-up used USDA indicators	Participants were retrospectively asked to report FI for the 12 months before and the 12 months after their cancer diagnosis	**Increase** from 29 to 36%, no p-value reported 58% persistently food secure 10% newly food insecure 26% persistently food insecure 3% resolved (food insecure before, but not after)
McDougall 2024 (47)	Food insecure adult patients with stage I–III breast or gynecological cancers and who completed initial cancer-directed therapy	Hunger Vital Sign for screening; follow-up used USDA indicators	All had completed initial treatment when FI was measured at baseline and again at 3-month follow-up.	**RCT Impact**: In a RCT of those food insecure during cancer treatment, those not receiving a cash-transfer had higher FI indicators (ate less than felt should, cut size of meal or skipped meal, food bought did not last, worried food would run out) than those who were given the cash transfer at 3-month follow up. Due to small sample size no formal statistical tests were done.

Abbreviations: FI = Food Insecurity; SNAP = Supplemental Nutrition Assistance Program; USDA = United States Department of Agriculture; HMH = Household Material Hardship, RCT = Randomized Controlled Trial

Notes: HMH for all studies included measures of FI, housing insecurity, and energy insecurity. Lin (2024) and Evans (2023) analyzed data from the same pediatric cohort.

Table 6:

Prevalence of Food Insecurity in Cross-Sectional Studies

Citation	Sample Notes	FI Measurement Tool	Reported Prevalence of Food Insecurity	Timing of Food Insecurity Measurement in Relation to Treatment
Anderson-Buettner, 2024 (38)	Native American cancer patients (age 18+) and cancer care providers	FI identified through interviews; no formal screening tool used	FI not measured; FI emerged as a challenge in treatment through qualitative responses	Various stages; Patients were in varied stages of treatment- some in pre-planning, some in treatment, and others were follow ups
Bona, 2015 (40)	Families with a child post-hematopoietic stem cell transplantation	USDA, six-Item	38% of families reported food, housing, or energy insecurity (composite number including FI) (~23% had FI based on a graph without numbers)	During treatment; FI was assessed during the post-transplant period. The median time from transplantation to survey completion was 132 days (IQR 99–198), meaning some of the reported FI could have occurred prior to transplant, as the survey asked about experiences in the past 12 months.
Garcia, 2018 (41)	NHIS data of adults aged 50 and older with specific chronic health conditions	NHIS, 10-items	14% of the whole sample (prevalence within the cancer population not reported)	Unspecified; participants asked if they had ever had a health condition. It's not specified how recent the diagnoses were.
Hallgren, 2023 (42)	NHIS data of cancer survivors and descriptive comparisons made to adults without cancer	NHIS, 10-items	11.5% for cancer survivors and 14.5% for non-cancer adults, not statistically significant	Unspecified; 88% were diagnosed >= 2 years prior to the survey date
Hao, 2024 (43)	Patients with a gastrointestinal cancer diagnosis receiving care	Hunger Vital Sign	8.3%	At diagnosis; FI status assessed when SDOH screening is administered during initial consultation
Kobritz, 2024 (44)	NHIS data of colorectal cancer survivors (and	USDA tool, unspecified	Early-onset CRC patients (who were younger) had 14.6% FI vs. average-onset	Unspecified; timing of FI measurement not specified in relation to treatment status. The survey happened an average of 19.3 years after diagnosis for those

	controls with no cancer history		CRC patients (who were older) had 6.6% FI; overall CRC patients 7.7% vs. the controls (without cancer hx) 3.7%, *p*= 0.011	with AO-CRC and an average of 8.2 years after diagnosis for those with EO-CRC.
Luo, 2023 (46)	Individuals living with cancer and qualifying for pantry services (income <130% of the federal poverty level)	One item from the adapted CARES-SF that asked about difficulty affording food	71.3% reported difficulty affording food	Unspecified; The survey happened at pantry registration. To qualify for food pantry registration individuals needed to be living with cancer.
Rosenberg , 2024 (48)	Racially and ethnically diverse sample of adult patients with metastatic breast cancer	Single-item derived from the USDA	Overall: 22% Hispanic: 42% Non-Hispanic Black (NHB): 46% Non-Hispanic White (NHW): 8% Asian American Pacific Islander (AAPI): 0% Other/multi-racial/unknown: 0% Statistically significant difference by race/ethnicity: *p* = 0.005	Unspecified; FI was assessed at the time of survey, not tied to treatment phase and treatment status was not reported. Time since diagnosis ranged widely (median: 9 years). Participants were contacted via phone, email, or approached in clinic following confirmation by a treating provider.
Shi, 2023 (49)	Hispanic adults with cancer in active treatment or follow-up/surveillance	One-item from the ENRICh FT tool In qualitative responses FI was identified as a subtheme for hardships	Participants documented on a scale from 0 "not affected at all" to 10 "affected a great deal" how much cancer and its treatment impacted their ability to pay for food. -Un/under-insured-Spanish: Median score of 4; 72.7% reported some impact -Un/under-insured-English: Median score of 8; 87% reported some impact), *p*	Various stages; survey not provided at a specific time. Participants were eligible for inclusion if they had a confirmed diagnosis of cancer and were in active cancer treatment or follow-up/surveillance care

			value of two groups is 0.22 -Insured-English: Median score of 0; 33% had some impact), *p* value of three groups is <0.001.	
Valenzuela, 2023 (50)	Black and Hispanic parents of children with cancer	Not specified- FI was measured as part of a 5-item HMH screening	42%	Various stages; 72% of children were receiving active cancer treatment at the time of survey. Eligible participants were parents of children who were between 6 weeks post-diagnosis and up to 1 year off therapy, capturing both families in active treatment and early survivorship
Valero-Elizondo, 2021 (51)	NHIS data of US adults with no ASCVD or cancer, ASCVD only, cancer only, and both ASCVD and cancer	NHIS, 10-items	10% for cancer only and 26% for those with both ASCVD and cancer	Unspecified; 55.3% were diagnosed > 5 years ago
Vaudin, 2022 (21)	NHANES data of U.S. adults aged ≥60 years	NHANES, 3-items	Total Sample including multiple health conditions: -5.7% had both economic and physical FI -25.0% had physical FI only -4.4% had economic FI only -64.9% were food secure Of those who had economic and physical FI, 21.6% had cancer Of those who had physical FI only, 31.9% had cancer Of those who had economic FI only, 15.1% had cancer Of those who were food secure, 26.2% had cancer	Unspecified; participants asked if they had ever had a health condition. It's not specified how recent the diagnoses were.
Zheng, 2020 (52)	NHIS data of U.S. adults with a self-	NHIS, 3-items	54.2% of cancer survivors aged 18−64 years old and	Unspecified; 83.4% were diagnosed >= 2 years prior to the survey date

	reported history of cancer		25.4% of cancer survivors aged ≥65 years reported some level of non-medical financial hardship (which was a composite variable including FI)	
Zheng 2023 (53)	NHIS data of children aged 5 to 17 with and without parental cancer history	NHIS, 3-items	Worry about food running out: 30.1% (vs. 20.1% without parental cancer), *p* value <.001; Food not lasting: 26.0% (vs. 16.7% without parental cancer), *p* value <.001; Inability to afford balanced meals: 16.9% (vs. 13.3% without parental cancer), *p* value .02	Unspecified; 81.2% were diagnosed >=2 years before the survey date
Zheng, 2020 (54)	NHIS data of cancer survivors and those without cancer	NHIS, 3-items	27% of young cancer survivors (aged 18-39) reported moderate or severe FI compared to 14.8% of adults (40-64) and 6.2% of older adults (age >=65yo). No comparison number for those without cancer.	Unspecified; more than 80% of cancer survivors were diagnosed >=2 years before the survey date

Notes. This table includes qualitative and mixed method studies.
Abbreviations: FI = Food Insecurity; NHIS = National Health Interview Survey; NHANES = National Health and Nutrition Examination Survey; USDA = United States Department of Agriculture; CRC = colorectal cancer, EO-CRC = early onset colorectal cancer, AO-CRC = average onset colorectal cancer, CARES-SF = Cancer Rehabilitation Evaluation System-Short Form; ENRICh= Economic StraiN and Resilience in Cancer; FT = financial toxicity; HMH = household material hardship

Pathway 1: Financial Mechanisms

Prevalence estimates alone do not explain the mechanisms driving FI. This section summarizes evidence for pathway 1 of the proposed food systems framework (Figure 1), with detailed findings presented in Table 7. This section is again categorized by longitudinal studies, cross sectional, and then qualitative results.

All six longitudinal studies (18,20,23,39,45,47) documented financial hardship, though its characterization varied widely. Measures of financial hardship included SNAP eligibility (39), work disruptions and income loss (18,20), financial toxicity (18), debt (23,45), coping strategies (45), and the impact of a cash transfer in an RCT (47). The clearest link of this mechanism between financial hardship and FI was observed in a RCT by McDougall 2024, providing a cash transfer to patients reduced indicators of FI and cost-related barriers to care and improved dietary quality among food insecure patients (47). Another clear link is from McDougall 2020 which found those who were newly FI after diagnosis were more likely to have debt of $1,000-$9,999 (OR 2.69; 95% CI, 1.08 to 6.71), although the type of debt was not specified (23)

Bona 2016 and Evans 2023 both found high rates of work disruptions and income loss among caregivers (18,20). In both studies, household material hardship significantly increased over time, with FI the most reported domain in Bona 2016 (20). Lin 2024 similarly found increases in household material hardship during treatment, with nearly half of families taking on debt, more than half reducing consumption, and about two in five losing savings or assets (45). While these studies did not directly test associations between financial hardship and FI, they consistently observed increases in both over time, suggesting the two may evolve in parallel during cancer treatment.

Cross-sectional studies consistently documented financial hardship among cancer survivors, though it was not always clear whether this was cancer-related or reflective of broader financial strain (21,38,40–44,46,48,51–54,56). Nearly all the 12 studies assessing financial hardship reported some

form of impact, though characterizations varied widely. Characterizations of financial hardship varied widely, including work disruptions (40,46), annual income loss (40), inability to pay bills (40) mean annual healthcare costs (41), medical financial hardship (42,52), financial strain (43), financial toxicity (44,49,51), financial distress (48), unmet economic needs (53), and financial worry (54). This heterogeneity complicates direct comparisons and limits synthesis across studies complicating direct comparisons.

One illustrative example is Bona 2015, which examined pediatric hematopoietic stem cell transplantation. In this study 80% of families reported work disruptions, 20% lost more than 40% of their annual income, and 26% were unable to pay bills; 38% also reported household material hardship, though FI was not reported separately (40). Notably, FI and financial hardship were not analytically linked, leaving the relationship implied rather than tested. Another example from a national dataset is Kobritz 2024, which found that colorectal cancer survivors were more likely than age-matched controls to report difficulty paying medical bills, had higher financial toxicity (OR = 1.344, p = .036), and were nearly twice as likely to report FI (44).

Zheng 2020a and Zheng 2020b using national data found an impact, but not for those ≥65 years old (52,54); these findings are elaborated in the disparities section with additional studies finding those who are younger are disproportionately impacted. Another national study, Valero-Elizondo 2021, found higher financial toxicity among survivors but no difference in FI compared with non-survivors (51). Finally, two national studies, one by Garcia 2018 and another by Hallgren 2023 found a relationship between medical financial hardship and FI, but this association did not differ between cancer survivors and those without a cancer history, implying that financial hardship may contribute to FI in a similar way across populations (41,42).

Qualitative results (38,49,50) further highlighted treatment-related hardships – including depleted or nonexistent savings, limited credit access, and immigration-related barriers (49), medical

bills, income loss, FI, and transportation difficulties (38,49,50). An illustrative quote was "When this began, I had to stop working, and therefore, I stopped having money, you know?" (49).

Pathway 2: Non-Financial Mechanisms

Only one study explicitly measured a non-financial pathway to food insecurity. Vaudin (2022) assessed physical FI, measured as difficulty shopping for, carrying, or preparing food. Their results found that cancer survivors had the highest prevalence of physical FI (31.9%) among older adults with chronic conditions. Notably, 25% of the overall sample—comprising individuals with a range of health conditions—were physically but not economically food insecure, and 65.4% of those with physical FI lived above the federal poverty line (21).

Other studies highlighted non-financial attributes that may impact FI, such as transportation barriers (n=7) (39,43,46,48,49,53,56), mobility or physical function issues (n=4) (38,46,48,49), and social isolation or lack of social support (n=2) (18,43) without classifying them as such. For example, Luo 2023 reported that fewer than half of participants with cancer drove to the grocery store, with others relying on rides, walking, or public transportation—6% did not shop at grocery stores at all (46). Other studies measured transportation insecurity found a range between 5.6-25% (39,43,48,56). In Shi 2023 up to 91.3% of participants reported that cancer and its treatment affected their ability to perform typical household responsibilities (49), while Luo 2023 another found that 58.5% reported difficulty doing chores (46). Social support also emerged as a relevant factor. In Hao 2024, 81.5% of participants reported social isolation (43), while interestingly Evans 2023 found social support mitigated the relationship between HMH and financial toxicity (18).

Table 7:

Evidence of Financial and Non-Financial Mechanisms to Food Insecurity

Citation	Type of Study	Study Objectives	Evidence of Financial Mechanisms (ex. financial toxicity, medical debt, loss of income, cost of treatment, forgoing care)	Evidence of Non-Financial Mechanisms
Anderson-Buettner, 2024 (38)	Qualitative	To identify barriers and facilitators to implementing financial hardship screening among Native American patients referred from I/T/U systems to a cancer center.	In qualitative responses patients identified multiple financial challenges to their cancer treatment related to logistics, such as transportation, lodging, and food during travel to the cancer center. Multiple patients reported psychosocial stress, including transportation concerns, stress in their work environment, FI, having enough funds to care for family and required medical treatment. Patients also described needing gas money, housing support, and assistance with food and utility costs.	Not classified as FI by the authors. Patients discussed physical barriers like mobility challenges, long-distance travel, and side effects. Family members were often required to assist.
Aziz-Bose, 2024 (39)	Secondary analysis of a prospective pediatric leukemia clinical trial cohort	To assess SNAP eligibility and participation rates among families of children with acute lymphoblastic leukemia enrolled in a clinical trial, and evaluate FI prevalence stratified by SNAP participation status.	37% of families were SNAP-eligible at diagnosis and 41% at 6 months (*p*-value not reported) 53% were food insecure at diagnosis and 55% at 6 months (McNemar's $p = 0.85$), indicating no statistically significant change in prevalence over time. There was turnover in status: 13 families became food secure, 15 became food insecure. (Paired data and *p*-value obtained through direct communication with the study author.) Changes in FI rates for the entire cohort (i.e., including families not eligible for SNAP) are not reported.	Not classified as FI by authors. Transportation insecurity at diagnosis: 8.6% of the full sample
Bona,	Cross	To describe the prevalence of	80% reported work disruptions	N/A

2015 (40)	sectional	family-reported income poverty and resource needs among families of children undergoing allogeneic HSCT, and to examine the impact of HSCT on parental employment and income at a pediatric referral center in New England	20% lost >40% of annual income due to HSCT, with low-income families had significantly more catastrophic losses (39% vs 7%, $p = .02$) 44% lost 11-40% of annual income due to HSCT; low-income families (28%) vs. high-income families (56%) 26% couldn't pay bills; some sold property or incurred debt	
Bona, 2016 (20)	Prospective Cohort	To assess the trajectory of HMH and financial hardship over the first 6 months of chemotherapy within a pediatric population.	56%, experienced some work disruption due to their child's illness with 15% of caregivers quitting or being laid off, and 37% reducing hours or taking unpaid leave Categorical % family income lost d/t work disruptions: <=10% loss: 53% for the total sample 11-40% loss: 22% for the total sample >40% loss: 25% for the total sample Low-income families lost significantly more income (median 49%) than higher-income families (median 6%) ($p = .02$) HMH increased from 20% to 29% (no p value recorded) and FI was the most common domain of material hardship at the 6-month mark.	N/A
Evans, 2023 (18)	Retrospecti ve cross-sectional survey	To examine the prevalence and predictors of HMH, financial toxicity, and income loss among caregivers of children with cancer and evaluate how work flexibility and social support affect financial burden.	58% of caregivers reported work disruptions such as parent quitting a job, being laid off, taking paid or unpaid leave (60% for low income, 79% for middle income, and 53% of high income caregivers) Categorical family income loss <=10% loss: 62% of caregivers 11-40% loss: 21% of caregivers >40% loss: 17% of caregivers	Not classified as FI by the authors. Overall, 19% of caregivers reported low social support, with significant differences by income: 32% of low-income, 14% of middle-income, and 9% of high-income caregivers ($p = .01$). Caregivers with baseline HMH had significantly lower odds of reporting normal social support (aOR 0.10, CI: 0.03–0.31). Social

			Income loss (>40%) was more common in the low-income group, but not statistically different (low 27% vs. middle 14% vs. high 12%, $p = .30$) FT reported by 81% of low-, 68% of middle-, and 44% of high-income caregivers ($p < .001$). Change in overall HMH is reported (36% to 52%, $p=.001$) but FI-specific change over time is not isolated.	support did not differ by race/ethnicity. In multivariable models, inclusion of social support reduced the association between HMH and financial toxicity (aOR reduced to 3.03, CI: 1.02–9.65)."
Garcia, 2018 (41)	Cross sectional (NHIS and MEPS data linked)	To estimate the incremental annual health care costs associated with FI among adults aged 50 and older, among specific chronic health conditions.	Among those with a history of cancer, the mean annual health care cost for food-insecure individuals was $10,240, compared to $9,710 for those who were food secure — a $530 cost difference. This difference was not statistically significant.	N/A
Hallgren, 2023 (42)	Cross-sectional	To examine the relationship between multiple dimensions of medical financial hardship (material, psychological, and behavioral) and household food security among adult cancer survivors in the U.S.	Measures of medical financial hardship was associated with household food security among cancer survivors: Material hardship (having problems paying or being unable to pay medical bills), $p = 0.027$ Psychological hardship (being very worried about medical bills), $p < 0.001$ Behavioral hardship (delaying medical care due to cost), $p = 0.007$) However, forgone care was not statistically significant. In a supplementary analysis, the authors tested whether the relationship between financial hardship and FI differed between cancer survivors and adults without cancer, and found no significant interaction effects.	N/A
Hao, 2024	Retrospecti	To compare patient-reported	Self reported FI correlated with financial strain	Not classified as FI by the authors.

(43)	ve cross-sectional	social determinants of health with census tract–based indicators in patients with gastrointestinal cancers	(p<0.001)	Approximately one third lived in a designated food desert (29.4%). 5.6% reported transportation insecurity. 81.5% reported social isolation. Financial FI was correlated with lack of transportation (p < 0.001) and social isolation (p = 0.03)
Kobritz, 2024 (44)	Cross-sectional	To assess the long-term impact of financial toxicity and FI among colorectal cancer (CRC) survivors	History of CRC independently predicted greater FT compared to age-matched controls with no cancer history (aOR = 1.344, p = .036) Patients with CRC were twice as likely to report struggling with FI compared to age-matched controls with no cancer history (7.7% vs 3.7%, p= 0.011) Additionally, those who were diagnosed earlier were more than double the odds of reporting FT and FI than those diagnosed at average onset	N/A
Lin, 2024 (45)	Retrospecti ve cross-sectional survey	To describe financial coping strategies (FCS) and access to financial assistance within the first year following pediatric cancer diagnosis	FCS in the 12 months after a pediatric cancer diagnosis found that 45% of families took on debt; 57% reported reducing consumption; and 40% lost savings and assets; 30% lost investments; 9.2% moved or relocated; 7.8% skipped meals; 5.0% got a second job. Families with low-to-middle income were significantly more likely to report incurring debt (p = .007), reducing consumption (p = .009), moving or relocated (p = .03), and skipping meals (p = .03).	N/A
Luo, 2023	Cross-	To examine demographic	74.2% reported cancer interfered with ability	Not classified as FI by the authors.

(46)	sectional	characteristics, quality of life, nutrition challenges, activities, and mental health among those living with cancer utilizing a hospital food pantry.	to work Kept from usual work ("work, school, or other daily activities") over the past 4 weeks: 62.3% 71.3% reported difficulty affording food (validated FI tool not used)	73.3% reported lack of energy 57.1% difficulty bending/lifting 58.5% difficulty doing chores 74.8% reported limiting physical activities Transportation limitations to grocery stores (only 45.3% drove; others relied on rides, public transport, walking, other, and 6% reported not shopping at a grocery store at all)
McDougall 2024 (47)	RCT Pilot Trial	To assess whether an unconditional cash transfer can reduce FI and improve quality of life, diet quality, and care adherence in food-insecure cancer survivors receiving cancer care	At baseline, approximately 40% of participants in both groups reported having experienced cost-related care disruptions. At 3-month follow-up, 40% of participants in the cash transfer group reported forgoing, delaying, or altering medical care due to cost, compared to 56% in the usual care group. Providing financial support decreased FI indicators (such as ate less than felt should, cut size of meal or skipped meal, food bought did not last, worried food would run out), although due to small sample size statistical analysis was not done.	N/A
McDougall, 2020 (23)	Retrospective cross-sectional survey assessing FI before and after cancer diagnosis	To assess the prevalence and predictors of FI among cancer survivors, and to evaluate associations between FI and forgoing, delaying, or altering medical care due to cost.	Newly food-insecure cancer survivors were also more likely to have debt of $1,000-$9,999 (OR 2.69; 95% CI, 1.08 to 6.71). Persistently food-insecure cancer survivors are also more likely to have debt >= 10,000 (OR 2.07, CI 1.16 to 3.68) FI was significantly associated with forgoing, delaying, or altering medical care due to cost — including medications, follow-up, mental health, and specialist visits.	N/A

Rosenberg, 2024 (48)	Cross-sectional survey study	To characterize the social, financial, and psychosocial experiences of racially and ethnically diverse adults with metastatic breast cancer	-Financial strain due to the cost of treatment and associated expenses: 58% -Reducing hours of employment: 40% -Worried about financial stability: 60% -Struggling with insurance companies during treatment: 40% -Worrying that treatment costs were not fully covered by insurance: 48% -difficulty paying the bills no matter what they did: 20% -able to pay their bills but only by cutting back on other things: 13% -reported there was a time in the past 12 months when they needed to see a doctor but could not because of cost: 6% -FI: 22% Minority race/ethnicities often had higher prevalence of hardship	Not classified as FI by the authors. 7% of participants reported transportation challenges. Additionally, PROMIS-29 scores indicated worse-than-average physical function and high levels of fatigue across the sample.
Shi, 2023 (49)	Mixed methods (qualitative cognitive interviews and cross-sectional survey)	To evaluate a Spanish version of the Economic Strain and Resilience in Cancer (ENRICh) measurement tool and to explore financial toxicity outcomes in a sample of Hispanic cancer patients	The uninsured/underinsured English speaking group reached a median score above 6, which the authors defined as FT. The uninsured/underinsured Spanish speaking group and insured English-speaking group reported financial impact but did not meet the threshold for FT (scores of 5.4 and 3.2 respectively). Through qualitative interviews, hardship emerged as a major theme. Subthemes within this category included: depleted or nonexistent savings, lack of credit and credit card access, FI, transportation difficulties, and immigration-related barriers. Another major theme was burdens, with subthemes including medical bills, lack of insurance, income loss, and impaired caregiving ability.	Not classified as FI by the authors. Transportation difficulty emerged as a subtheme within the "hardships" category during qualitative interviews Participants rated from 0 ("not affected at all") to 10 ("affected a great deal") the extent to which cancer and its treatment impacted their ability to contribute to typical household responsibilities UN-Spanish: Median score = 6 (IQR 3–10); 82.6% reported some impact UN-English: Median score = 9 (IQR 6–10); 91.3% reported some impact (p = .21 vs. UN-Spanish)

				INS-English: Median score = 3 (IQR 0–8); 62.1% reported some impact (p = .01 across all groups)
Valenzuela, 2023 (50)	Sequential mixed-methods study Quantitative: Cross-sectional survey Qualitative: Semi-structured interviews	To explore experiences of HMH—including housing, food, utility, transportation insecurity—among Black and Hispanic parents of children with cancer	Nearly three-fourths (73%) of parents reported HMH including housing (48%), food (42%), utility (25%), or transportation (25%) insecurity. Twenty-six parents (43%) reported two or more domains of HMH simultaneously. The overarching theme for qualitative interviews was that HMH is highly prevalent. -Participants described increased financial strain related to treatment, transportation (e.g., gas, parking) and utility costs (e.g., higher heating or electric bills) during their child's cancer care -Employment disruption reported during interviews (reducing hours, quitting jobs) leading to increased financial strain and HMH	Not classified as FI by the authors. Transportation insecurity was reported by 25% of participants.
Valero-Elizondo, 2021 (51)	Cross-sectional	To assess and compare financial toxicity, including FI, among adults with cancer, ASCVD, both conditions, or neither, using a nationally representative sample.	Prevalence of any FT indicators (including FI, financial distress, difficulty paying medical bills, cost-related medication nonadherence, and cost related delayed/forgone medical care): 38% (neither), 41% (cancer), 54% (ASCVD), 55% (both) FI: 10% (neither), 10% (cancer), 23% (ASCVD), 26% (both)	N/A
Vaudin, 2022 (21)	cross-sectional	To estimate the prevalence of economic and physical FI among older adults (≥60 years) and to evaluate their associations with socioeconomic factors, diet	Of those who reported only economic FI 15.1% had a history of cancer	Classified as FI by the authors. Of those with only physical FI those with cancer represented the largest portion of any health condition at 31.9%

		quality, depression, and health conditions.		Of those with both economic + physical FI 21.6% had cancer 25% of the whole sample (not cancer specific) were physically food insecure but not economically food insecure Of those with physical FI, 26.7% lived alone and 65.4% lived above the federal poverty threshold
Zheng(a), 2020 (52)	cross-sectional	To assess whether medical and non-medical financial hardships are independently associated with healthcare utilization and self-rated health among cancer survivors, and whether greater hardship intensity is linked to worse outcomes	Medical financial hardship was measured using a composite score/level including problems paying bills, paying off bills over time (such as through a loan), worry about paying bills, delaying care, or forgoing care. Cancer survivors aged 18−64 years: Level 1 32.4% (least severe hardship) Level 2 28.4% Level 3 21.6% Level 4 17.6% (most severe hardship) Cancer survivors aged ≥65 years: Level 1 62.8% Level 2 23.6% Level 3 9.2% Level 4 4.3% Non-medical hardship was measured using a composite score/level including FI, worries on retirement, standards of living, and being able to pay monthly bills and rent. Cancer survivors aged 18−64 years: Level 1 45.8% Level 2 27.1% Level 3 15.6%	N/A

			Level 4 6.1% Level 5 5.4% Cancer survivors aged ≥65 years: Level 1 74.6% Level 2 16.7% Level 3 5.7% Level 4 1.6% Level 5 1.4%	
Zheng, 2023 (53)	Cross-sectional	To examine whether having a parent with a history of cancer was associated with unmet economic needs among children aged 5–17 years, including FI, financial worry, and transportation barriers to care.	Prevalence of unmet economic needs for parents with cancer reported vs those without: Worry about paying monthly bills: 44.8% vs. 37.9%, p = .001) Worry about housing costs: 35.7% vs. 30.7%, p = .009) Delayed child medical care because of lack of transportation: 3.6% vs. 1.6%, p < .001 -Worry about food running out: 30.1% vs. 20.1%, p value <.001 -Food not lasting: 26.0% vs. 16.7%, p value <.001 -Inability to afford balanced meals: 16.9% vs. 13.3%, p value .02	Not classified as FI by the authors. Delayed child medical care because of lack of transportation: 3.6% vs. 1.6% (OR = 2.31, p < .001)
Zheng(b), 2020 (54)	Cross-sectional (using NHIS 2013–2017 data)	To compare financial worry and FI between cancer survivors and those without a cancer history, and to identify demographic and clinical factors associated with these outcomes among survivors.	Cancer survivors aged 18 to 39 years, compared with individuals without a cancer history reported being very worried about: Retirement 25.5% vs 16.9%, p<.001 Standard of living 20.4% vs 12.9%, p<.001 Monthly bills 14.9% vs 10.3%, p=.002 Housing costs 13.6% vs 8.9%, p=.001 And reported the following was "often true" Food running out 7.9% vs. 4.6%, p=.004 Food not lasting 7.6% vs. 3.3%, p=.003 Can't afford balanced meals 6.3% vs. 3.4%, p=.007 When comparing different age groups among	N/A

			cancer survivors (>=65 as the referent), younger age was associated with greater likelihood of reporting higher intensities of financial worry, age, and FI (all statistically significant)	

Abbreviations: *I/T/U = Indian Health Service, tribal health facility, or IHS-supported urban program; FI = Food Insecurity; SNAP = Supplemental Nutrition Assistance Program; HSCT = Hematopoietic Stem Cell Transplantation; HMH = Household Material Hardship; FT = Financial Toxicity; NHIS = National Health Interview Survey; MEPS = Medical Expenditure Panel Survey; RCT = Randomized Controlled Trial; PROMIS-29 = Patient-Reported Outcomes Measurement Information System-29; ENRICh = Economic Strain and Resilience in Cancer; UN-Spanish = Uninsured/Underinsured, Spanish-speaking group; UN-English = Uninsured/Underinsured, English-speaking group; INS-English = Insured, English-speaking group; ASCVD = Atherosclerotic Cardiovascular Disease*

Income-Related Disparities

Income status was the most consistent predictor of financial hardship or FI across studies, with lower income linked to greater risk in all ten studies that assessed this (18,20,21,23,40,42,45,51,53,54). For example, Lin 2024 found that low-and middle-income families had significantly higher odds of incurring debt (p = .007), reducing consumption (p = .009), relocating (p = .03), and skipping meals (14% vs. 1.5%; p = .03) compared to high-income families (45). Evans 2023 found that higher-income caregivers had greater access to work flexibility, which was significantly associated with lower financial toxicity (OR = 0.88; p = .002) (18).

While low-income families experienced the greatest FI, middle- and high-income families were also affected, primarily as a result of income lost or work disruptions during cancer treatment. Evans (2023) found that 27% of low-income, 14% of middle-income, and 12% of high-income families reported income loss over 40% (p = .30), and work disruption were most common among middle-income caregivers (79%), followed by low- (60%) and high-income (53%). In a prospective cohort study by Bona 2016, families who newly developed HMH at 6 months were more likely to have had higher baseline incomes (p=0.04) (20).

Age-Related Disparities

Age was also associated with financial hardship or FI across studies, with younger cancer survivors at greater risk in 7 (21,23,42,44,51,52,54) of the 9 that assessed this (49,53). For example, Zheng 2020b found that young adult survivors (18–39) reported significantly higher rates and greater severity of both financial worry and FI (p < .001) compared with same-age peers without a cancer history. Among survivors aged 40–64, findings were less consistent, and for those ≥65, results were similar to peers without cancer (54). Zheng 2020a also reported that those under 65 were more likely

to experience medical and non-medical financial hardship and to live below 200% of the federal poverty level (52). McDougall 2023 found newly food-insecure survivors were diagnosed at younger ages than their food-secure counterparts (mean, 49 years v 52 years; OR, 0.95; 95% CI, 0.91 to 0.99)(23) and in Kobritz on early-onset CRC patients (whose mean age of diagnosis was 38.9 SD 10.2) had over twice the FI prevalence of those with average-onset CRC (whose mean age of diagnosis was 65.8 SD 10.4) (14.6% vs. 6.6%, $p = .011$), with elevated financial toxicity persisting long after diagnosis (44).

Race and Ethnicity Related Disparities

Race and ethnicity emerged as predictors of financial hardship and FI across studies, with Black and/or Hispanic individuals at greater risk in 8 of 9 studies that assessed this (18,21,23,42,44,48,51,53). Evans 2023 reported disparities only for Hispanic individuals, and found higher risk of HMH at diagnosis but no significant differences in financial toxicity or income loss (18), while McDougall 2020 found that newly or persistently food insecure patients were more likely to be Hispanic (23). In contrast, Zheng 2020b found no systematic differences in the intensity of financial worry or FI by race/ethnicity (54).

In addition to the comparative studies described above, two studies, Shi 2023 and Valenzuela 2023 focused exclusively on Black and/or Hispanic populations (49,50) which precluded comparisons with other groups. Both reported some of the highest FI rates across included studies, although they were conducted in low-income populations. In Valenzuela 2023 (50) where the vast majority of participants were Black or Hispanic, qualitative interviews revealed that HMH was highly prevalent, with themes consistent across racial/ethnic groups.

Discussion:

Summary of Key Findings

Across 21 U.S.-based studies—most published since 2020 and largely cross-sectional—FI among people with cancer was common but varied widely, ranging from 6.2-72.7% (omitting one study where FI was an inclusion criteria (47) depending on setting, population, and measurement approach. In longitudinal studies, financial hardship was consistently observed with cancer care causing work disruptions, income loss, and reliance on financial coping strategies, in addition to an elevation in FI rates in most studies. Analyses of national datasets were mixed on whether cancer history independently predicted FI apart from financial hardship, particularly in older age groups. Across the literature, individuals with low income, younger age, and racial or ethnic minority backgrounds were consistently found to be disproportionately affected by both FI and financial hardship which is in line with previous research (58–60). There was limited longitudinal evidence, but where present generally suggested increases in FI or HMH during treatment.

Non-financial mechanisms were occasionally described but rarely measured directly, with only one study formally assessing physical FI. One likely reason for this gap is the dominant way FI is measured in the United States. Most tools rely primarily on money-related or financial access questions, reflecting the USDA Food Security Module and similar adaptations. Two systematic reviews Ashby et al. (2016) (61)and Manikas et al. (2023) (62) confirmed that FI measures overwhelmingly emphasize financial access, while underrepresenting other domains such as utilization, availability, and stability. The research related to pathway 2 in the model was very narrow, but overtime this framework could be expanded to include the 4 different FAO domains as pathway to FI in oncology care. Given these key findings, there are multiple implications, as well as recommendations for future research and clinical cancer care, which are described further below.

The findings highlight that several groups of people are especially vulnerable to FI during cancer diagnosis and treatment, though study design often prevents causal linkage of these factors (i.e., it may be that FI is high at the time of diagnosis). Lower-income, younger, and racially and ethnically diverse households and individuals had higher levels of FI, which is broadly commensurate with prevalence of FI across the population, beyond those with cancer. Income, as expected, was closely associated with both financial hardship and FI, aligning with broader literature on FI across populations (63). However, notably financial challenges in cancer care were not exclusive to the lower income population, underscoring the financial impact of cancer and its care.

Younger adults faced increased vulnerability to financial hardship and FI, likely due to lower wealth accumulation (64), caregiving responsibilities (65), and a lack of fixed income making loss of work more impactful. In contrast, older cancer survivors (≥65 years) consistently reported lower prevalence of FI compared with younger groups, a pattern that may reflect the stabilizing role of Medicare eligibility and Social Security benefits. One study further found that younger survivors had lower incomes and were less likely to have private insurance, whereas older survivors reported higher incomes and were more often covered by supplemental private insurance in addition to Medicare (54).

Race and ethnicity patterns are consistent with prior research showing that Black and Hispanic individuals are disproportionately affected by socioeconomic hardship (65,66). Among Hispanic populations, this disparity may be partially explained by language barriers and reduced access to insurance and safety-net programs (49,67).

Methodological constraints within the current evidence base limited both the strength and clarity of interpretation. Causality and directionality were difficult to establish, as many studies relied on cross-sectional designs that capture only a single point in time. This made it unclear how much FI was present before treatment versus how much was influenced by treatment. Furthermore, many

studies did not distinguish when their surveys were conducted, providing unclear evidence about how and when within the cancer diagnosis and treatment process FI may have occurred, and preventing clear comparisons of FI prevalence and changes.

The AND quality assessment tool was applied in the absence of a gold-standard instrument for this context. Many studies received a neutral (N) rating due to sampling constraints, reliance on non-validated tools, and either limited statistical analysis or lack of adjustment for potential confounders. While the use of this tool was necessary for the review process, additional criteria may be useful for evaluating studies in this emerging area.

Notably, some of the most informative evidence came from prospective studies conducted with patients actively undergoing cancer treatment, as well as from studies that employed non-validated instruments. This highlights a tension between methodological rigor and the need for tools that adequately capture the complexity of food insecurity in oncology populations. Current validated measures, such as the USDA modules, are incomplete for this purpose. A key research implication of this review is the need for the development of new, oncology-relevant food insecurity measures that incorporate broader domains beyond financial access, reflecting the multidimensional nature of food security.

Research Implications:

Improving study design for causal interpretation, as well as clarity of measurement and timing is recommended for future research, which should prioritize longitudinal designs. Other important directions include the development and validation of oncology-specific FI measures that capture employment disruptions, income loss, out-of-pocket costs, insurance and benefit changes, transportation and functional barriers to food access, neighborhood food environments (e.g., food deserts), and broader dimensions of nutrition security.

Better Assessment of Non-financial Mechanisms

A single study directly measured a non-financial pathway, highlighting a significant gap in literature. Notably, this study found that 65.4% of those experiencing physical FI lived above the federal poverty level, underscoring that non-financial FI can exist independently of economic hardship. Although several studies described potential non-financial contributors (e.g., transportation barriers, functional limitations, lack of social support), these factors were rarely conceptualized or measured as FI. To some extent this is understandable: for example, transportation barriers may not limit access for someone living near a full-service grocery store, poor physical health may not affect food access for those with reliable caregivers, and lack of social support may not impede food preparation for able-bodied individuals. Nevertheless, future research should more explicitly consider non-financial mechanisms that affect FI such as: physical limitations procuring food, transportation barriers, residence in a food desert, limitations in food preparation or self-feeding, physiological impacts of cancer and it's treatment hindering adequate dietary intake and quality (ex. dysgeusia and dysphagia), MNT coverage for patients struggling with nutrition related challenges to meet with dietitians, inadequate home food-preparation equipment, lack of safe water and sanitation, limited diet diversity, and changes in FI status over the time of care.

Clinical implications

These findings provided evidence that FI was prevalent among cancer patients, including in some populations both at diagnosis and throughout treatment and post-treatment. As a result, screening for FI at diagnosis and during treatment is critical to capture unique vulnerabilities and changes over time. Several studies in this review found patients receptive to screening (38,50). Screening efforts may be especially important for younger, low-income, and racially or ethnically minoritized patients, who were consistently identified as being at greater risk of FI in this review.

One included study noted that FI remained high even among SNAP participants, suggesting existing programs may be insufficient (39). 2022

This is where direct assistance—such as food vouchers or cash transfers—may help address short-term unmet needs, as demonstrated in McDougall 2024 (47). Other implications include prioritizing resource identification and referrals. Since transportation limits access, onsite pantries, transportation to affiliated pantries, or food delivery services can be useful. Utilizing nutrition and social work services may also be helpful. Discharge planning could explicitly assess home food access, the patient's capacity to shop and prepare meals, and caregiver availability.

Strengths and Limitations

Strengths include being the first to synthesize both financial and non-financial mechanisms linking cancer and FI, applying a comprehensive search strategy with a pre-registered approach, and introducing a novel conceptual framework to guide future research and measurement in oncology settings. The research was limited by the use of a single reviewer to conduct data extraction and the exclusion of grey literature which may have resulted in the omission of relevant studies.

Conclusion:

In summary, cancer and its treatment introduce both financial and non-financial hardships that may increase the risk and prevalence of FI. Despite this, most research and screening tools focus narrowly on financial access as a mechanism for FI, neglecting non-financial dimensions such as physical ability to obtain or prepare food—critical concerns for many oncology patients. Furthermore, current methodological study designs are limited in their ability to track changes in FI over time, and to compare FI across populations given lack of detail about survey design and implementation or longitudinal nature. Improving future FI and cancer-related studies through new

measurement tools, longitudinal or clearly documented designs, and with a broader understanding of FI, consistent with the FAO's four domains, is essential to improving nutritional care and health outcomes in this population.

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CHAPTER 4: PREVALENCE AND PREDICTORS OF FOOD INSECURITY AMONG CANCER PATIENTS AT A LARGELY RURAL NORTHEASTERN HOSPITAL

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Sending for hopeful publication at: Cancer Causes & Control

Abstract

Purpose: Food insecurity (FI) is an emerging concern in cancer care, yet little is known about its prevalence and predictors at the time of diagnosis, particularly in rural populations. This study examined FI among newly diagnosed cancer patients among a predominantly rural population at a Northeastern academic medical center.

Methods: In this cross-sectional study, patients were screened for risk of FI at diagnosis in 2023-2024 using the Hunger Vital Sign, a validated two-item tool. Screening data were linked to the electronic health record to obtain demographic, geographic, insurance, and clinical variables including primary cancer diagnosis and comorbid health conditions.

Results: Among 637 patients, 3.9% were at risk of FI, lower than both state and national averages at the time of the survey. Multivariable analysis identified several significant predictors of FI. Higher odds were observed among men, patients residing in non-metropolitan areas, and those insured through Medicaid or Medicare. FI was also associated with lung cancer, hyperlipidemia, and stroke. Conversely, lower odds were observed among patients aged 67 years or older, those who were married or partnered, and those with hypertension or chronic kidney disease.

Conclusions: This study is among the first to assess FI at diagnosis in a largely rural, non-metropolitan cancer population. Findings suggest that rurality, demographic factors and cancer type are important potential predictors of FI at diagnosis, providing opportunity for targeted screening for high-risk groups and ensuring that populations at risk of underdiagnosis are not overlooked. Future research should assess longitudinal changes in FI during treatment and include non-financial aspects of food access.

Introduction:

Identifying food insecurity (FI) among cancer patients at diagnosis and throughout treatment is critical due to its potential negative outcomes for cancer patients. FI among individuals with cancer is associated with delays or forgoing care, alterations to medication regimens—particularly in those newly experiencing FI (1)--increased risk of financial toxicity (2), and greater likelihood of malnutrition (2). Malnutrition in cancer typically arises from a combination of inadequate intake and disease-specific metabolic disturbances (3) and is associated with treatment-related toxicity (4,5), treatment discontinuation(6), ER visits(4), hospitalizations (4,6), and mortality (5,7–9). An estimated 10–20% of cancer-related deaths are attributable to malnutrition rather than the cancer itself (10). These outcomes underscore the importance of identifying nutrition-related challenges, including FI, early in the cancer care journey, and of understanding the complex relationship between FI and cancer.

Cancer patients may be more vulnerable to FI than the general population both before and after diagnosis. As FI is highly associated with income, FI is associated with a cancer diagnosis (11), likely due to its association with lower diet quality (12–14), which is linked to increased cancer risk (15–18); reduced likelihood of being up to date on cancer screening (19–21); and healthcare access hardship, including lower rates of health insurance coverage, lack of a usual source of care, and inability to afford care (22–25). Additional research further demonstrates that low-income status is associated with other cancer risk factors such as reduced access to high-quality housing (26), smoking (27), and employment in high-risk or polluting industries (28).

Post diagnosis, financial hardship resulting from cancer and its treatment can also contribute to FI, including new FI. In a systematic literature review, out of pocket expenses for cancer treatment in the United States ranged from $180 to $2,600 per month, with an average of approximately $300 per month (29). This financial strain may force families and individuals to reduce spending on essential needs such as food (1,30–35). FI can exacerbate financial hardship. For example, those who

are food insecure have higher healthcare expenditures compared to food-secure adults (36). McDougall (1) describes the relationship between FI and chronic illness as bidirectional and self-reinforcing- chronic illness can create financial strain that leads to FI, while FI can force trade-offs between food and medical care, worsening health and deepening financial hardship.

Existing studies report wide variation in FI prevalence for patients in active treatment or post treatment, ranging from 4.0% to 83.6% (37), compared to an estimated at 13.5% in the U.S. general population in 2023 (38). In a scoping review, higher rates of FI are observed in populations receiving cancer care at Federally Qualified Health Centers (FQHCs), among low-income patients, among younger patients, and in racially and ethnically diverse populations (37). Recent studies confirm these associations (32,39,40) and highlight additional groups at elevated risk, including those living in rural areas, facing transportation barriers, and experiencing housing instability (39,41); uninsured patients (1,39), those enrolled in Medicaid (1), or on public insurance more broadly (42); individuals with lower educational attainment (43), unmarried status (1), higher levels of debt(1), and greater burden of comorbidities (1,42). These patterns point to populations that may require targeted interventions to prevent and address FI.

Many studies on this topic are conducted in urban areas (30–35,44–46). A single study focuses on a rural facility serving a 29-county rural region in Eastern North Carolina—in this study approximately half of the cohort resided in a rural county (50.5%)—and the overall FI prevalence was 8.3% (47). Many studies also use national datasets that may not reflect FI status at diagnosis or during treatment (48–52), or focus on populations where high FI prevalence is expected (30,45,46,53–55), creating the need for studies conducted in different populations. Several other gaps in the literature limit understanding of FI among cancer patients and hinder effective care and prevention. Few studies examine differences by cancer type, preventing patterns from emerging (1,42). While some studies specify when FI is measured (1,33–35,44,46), the majority do not. Without this, it is difficult to distinguish pre-existing FI from FI that emerges as a result of cancer care –

potentially as the result of financial toxicity (35) defined as the harmful impact of treatment costs on quality of life (56) and makes it difficult to contextualize reported prevalence estimates. Lastly, there is a gap that many clinical centers and hospitals do not routinely screen for FI (57,58). Without systematic screening, patients at risk may go unrecognized and unconnected to supportive services.

Understanding FI prevalence at diagnosis and identifying at-risk subgroups is essential to guide routine screening in oncology settings and to inform the development of targeted interventions. Baseline FI data can also help distinguish pre-existing FI from FI resulting from the financial and non-financial impacts of cancer and its treatment. This study aims to fill these existing gaps by exploring data The University of Vermont Medical Center (UVMMC), is an academic health system providing primary, secondary, and tertiary services, serving residents of Vermont and northern upstate New York, both of which are predominantly rural. Vermont is the most rural state in the country, with the most recent U.S. Census finding that it has the highest proportion of its residents (64.9%) living in a rural area (59). Northern New York is similar, with a significant portion of the population in each of the Northern counties serviced by UVMMC including predominantly rural residents.

The goal of this study was to assess the prevalence and predictors of FI among cancer patients receiving care at UVMMC. Specifically, the objectives were to (1) measure FI prevalence approximately six weeks after cancer diagnosis and (2) identify demographic, geographic, insurance, and clinical factors associated with FI in this patient population. The central research question guiding this analysis was: What are the demographic, geographic, insurance, and clinical predictors of FI among cancer patients at UVMMC recently diagnosed with cancer?

Methods:

In January 2023, the oncology department at the UVMMC began screening patients for FI using the Hunger Vital Sign, a two-item validated tool adapted from the U.S. Household Food

Security Survey Module and recommended for clinical use by the American Academy of Pediatrics (60). While primarily designed for screening, this tool is frequently used as a measurement instrument for FI (1,33,35,47). The questions are as follows:

Hunger Vital Sign Questions

1. Within the past 12 months, we worried whether our food would run out before we got money to buy more.
2. Within the past 12 months, the food we bought just didn't last and we didn't have money to get more.

For each Hunger Vital Sign question, patients selected: *often true*, *sometimes true*, *never true*, or *decline to answer*. Participants were classified as food insecure if they responded *often true* or *sometimes true* to either item. Those who answered *never true* to both items were categorized as food secure. Patients who declined to answer either question or left the survey blank were excluded from the analysis.

Screening was conducted approximately six weeks after cancer diagnosis. Paper forms, distributed by social workers, included the Hunger Vital Sign questions as well as items assessing practical, physical, emotional, and family concerns, and a self-reported distress score (0–10 scale). Responses were manually entered into an Excel spreadsheet and linked to electronic health record data to extract additional demographic and clinical variables, including: medical record number, date of birth, age, sex assigned at birth, race/ethnicity, Hispanic or Latino origin, primary language, marital status, ZIP code, state, documented disability status, primary and secondary insurance type, primary cancer diagnosis, and comorbid health conditions (type 2 diabetes mellitus, hyperlipidemia, hypertension, heart failure, stroke, coronary artery disease, chronic kidney disease, and malnutrition). Data collection concluded in April 2024, resulting in a 16-month dataset. This project was conducted as part of a quality improvement initiative and was exempt from Institutional Review Board (IRB) review.

Inclusion and exclusion criteria:

Patients were eligible if they had a recent cancer diagnosis, filled out the two-item screener, and were initiating treatment at UVMMC. Patients with chronic lymphocytic leukemia (CLL) were included if they were starting treatment.

Patients were excluded if they were not initiating treatment (e.g., declined treatment, entered hospice or palliative care, died prior to treatment, relocated, or sought a second opinion without initiating care at UVMMC) or if they had a long-standing cancer diagnosis and were returning only for follow-up visits.

When applicable, the most recent cancer diagnosis date was used. For example, if a patient was previously treated for breast cancer presented with a new or recurrent cancer (e.g., melanoma), the most recent diagnosis was recorded to better reflect the financial context at the time of screening. For patients with multiple concurrent cancers, the primary cancer site was documented.

To assess statistically significant differences between food secure and insecure patients, we utilized chi-square tests (i.e., for binary variables) and paired t-tests (i.e., for continuous variables) as needed depending on the distribution of the variables. Given the binary distribution of our dependent variable of interest (food security), a multilevel random effects logit model was used to examine associations between FI and the demographic and clinical variables collected. Since food security may also be affected by other factors that could be geographically clustered (e.g., policy, transportation), we utilize two random effects in the model at the zip code and state level. Furthermore, we use robust standard errors in the reporting. Cancer types with fewer than 7% of the population diagnosis (i.e., 40 or fewer people (Head/neck, urinary, and melanoma cancers) were omitted from the model for collinearity. Several variables were transformed into binary variables in the model, including race/ethnicity (1= non-white and/or Hispanic, 0= White, Non-Hispanic), rurality (1= RUCA code 4-10 (i.e. rural), 0= metropolitan), age (1= 67 or older (the median age), 0=

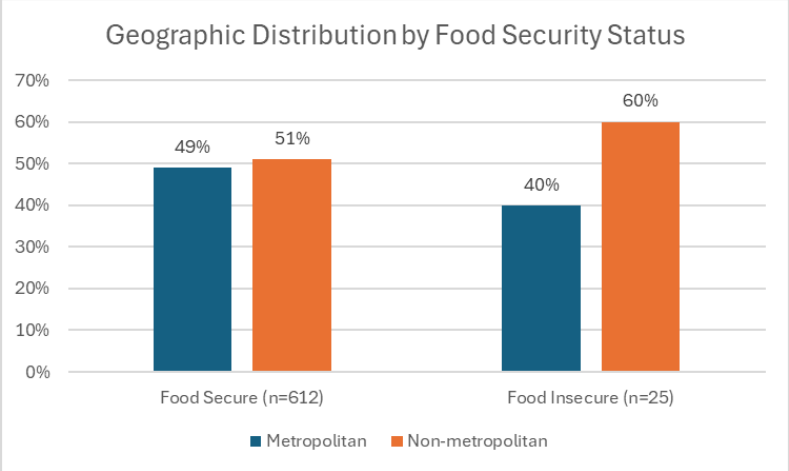
younger than 67), and married status (1= married or life partner, 0= single, legally separated, divorced or widowed).

Results:

A total of 637 patients were included in the analysis, results shown in Table 8. The most common primary cancer types were breast (40.3%), blood and lymphatic malignancies (9.7%), and upper gastrointestinal cancers (9.1%). Comorbid conditions were common in the cohort, with 42.7% having hypertension, 37.8% hyperlipidemia, and 17.6% Type 2 diabetes. More than half of participants were insured through Medicare (58.2%), with 12.2% enrolled in Medicaid, 6.1% dually enrolled in Medicare and Medicaid, and 35.6% were covered by private insurance. The mean age was 65.3 years (SD = 13.6). Most participants were women (59.3%), identified as White (94.7%), spoke English as their primary language (98.6%), and were married (60.8%). Most resided in Vermont (76.6%) and more than half lived in a non-metropolitan area (51.1%) (Figure 6). Twenty-five participants (3.9%) screened positive for FI.

Figure 6:

Geographic Distribution by Food Security Status



Notes. Percentages reflect the proportion of metropolitan and non-metropolitan patients within each food security group. Among food-secure patients (n=612), distribution was nearly even (49% metropolitan, 51% non-metropolitan). Among food-insecure patients (n=25), a greater share resided in non-metropolitan areas (60% vs. 40%).

T tests and chi-square tests revealed several statistically significant differences in demographics between food secure and insecure respondents. Compared with food-secure patients, those experiencing FI were younger on average (58.8 vs. 65.6 years, p= 0.015). Food insecure respondents were also more likely to be disabled (p=0.005), not be married or have a life partner (p=0.006), be insured through Medicaid (p=0.031), and have a lung cancer diagnosis (p=0.004).

Exploring multiple predictors of FI together through multivariate mixed effects models further highlights several demographic and clinical factors were associated with increased or decreased odds of FI (Table 9, Figure 7). Increased odds were observed among patients who were male at birth (OR = 2.77, 95% CI 1.88–4.10, p < .001) and living in nonmetropolitan areas—including micropolitan, small town, and rural classifications— (OR = 1.48, 95% CI 1.03–2.12, p = .034). Being over 67 years old (OR = 0.13, 95% CI .11-.17, p <.001), and marriage or life partnership was associated with lower odds of FI (OR = 0.31, 95% CI 0.22–0.43, p < .001). Regarding insurance, food-insecure patients had increased odds of Medicaid coverage (OR =3.28, 95% CI 2.62-4.10, p < .001) and Medicare coverage (OR = 5.40, 95% CI 3.68–7.93, p < .001).

FI was also associated with increased odds of lung cancer (OR = 6.443, 95% CI 1.37–30.42, p = .019). Breast cancer was borderline significant (p = .052), suggesting a weak trend toward increased odds but not statistically significant. Other cancer variables not shown in Table 9 were omitted from modeling due to small sample sizes. For comorbidities, food-insecure patients had increased odds of hyperlipidemia (OR = 3.25, 95% CI 2.10-5.02, p < .001) and stroke (OR = 5.49, 95% CI 3.42–8.82, p < .001), but decreased odds of hypertension (OR = 0.26, 95% CI 0.21–0.32, p < .001) and chronic kidney disease (OR=0.54, 95% CI 0.38-0.76, p<.001).

Table 8:

Patient Demographic, Geographic, Insurance, and Clinical Characteristics by Food Security Status

Characteristic	Total (n= 637)	Total (%)	Food Insecure (n=25)	FI (%)	Food Secure (n=612)	FS (%)
Age*, average (SD)	65.3, SD 13.6		58.8, SD 11.01		65.6, SD 13.68	
Sex at birth						
Female	378	59.3	14	56.0	364	59.5
Male	259	40.7	11	44.0	248	40.5
Gender Identity						
Female	365	57.3	13	52.0	352	57.5
Male	257	40.3	11	44.0	246	40.2
Nonbinary/They/Them	2	.3	1	4.0	1	.2
Not reported	13	2.0	0	0	13	2.1
Race/Ethnicity						
White	603	94.7	23	92.0	580	94.8
Asian	9	1.4	0	0	9	1.5
African American	4	.6	0	0	4	.7
American Indian or Alaskan Native	2	.3	1	4.0	1	.2
Native Hawaiian/Pacific Islander	2	.3	0	0	2	.3
Other	2	.3	1	4.0	1	.2
Multi Race	1	.2	0	0	1	.2
Declines	14	2.2	0	0	14	2.3
Hispanic or Latino						
Yes	5	.8	0	0	5	.8
No	617	96.9	25	100.0	592	96.7
Declined to Respond	15	2.4	0	0	15	2.5
Primary Language						
English	628	98.6	24	96.0	604	98.7
Other	9	1.4	1	4.0	8	1.3
Marital Status						
Single	116	18.2	9	36.0	107	17.5
Married	387	60.8	8	32.0	379	61.9
Legally Separated	4	.6	1	4.0	3	.5
Divorced	60	9.4	4	16.0	56	9.2
Life Partner	8	1.2	1	4.0	7	1.1
Widowed	62	9.7	2	8.0	60	9.8
State						
Vermont	488	76.6	19	76	469	76.6
New York	139	21.8	6	24	133	21.7
Other	8	1.2	0	0	8	1.3
Information Unavailable	2	.3	0	0	2	.3
Ruca Code (1-10)						

Metropolitan (1-3)	310	48.7	10	40.0	300	49.0
Micropolitan (4-6)	117	18.4	5	20.0	112	18.3
Small Town (7-9)	101	15.9	6	24.0	95	15.5
Rural (10)	107	16.8	4	16.0	103	16.8
Information Unavailable	2	.3	0	0	2	.3
Disabled*	29	4.6	4	16.0	25	4.1
Insurance*						
Medicare	371	58.2	15	60.0	356	58.2
Medicaid	78	12.2	7	28.0	71	11.6
Both Medicare and Medicaid	39	6.1	3	12.0	36	5.9
Private	227	35.6	6	24.0	221	36.1
Primary Cancer Diagnosis						
Blood and Lymph System	62	9.7	0	0	62	10.1
Breast	257	40.3	10	40.0	247	40.4
Colorectal/Anal	47	7.4	2	8.0	45	7.4
Genitourinary	40	6.3	3	12.0	37	6.0
Gynecological	1	.2	0	0	1	.2
Head and Neck	19	3.0	2	8.0	17	2.8
Lung	53	8.3	6	24.0	47	7.7
Melanoma	25	3.9	0	0	25	4.1
Neurologic	5	.8	0	0	5	.8
Non-melanoma Skin Cancer	8	1.3	0	0	8	1.3
Other	11	1.7	0	0	11	1.7
Pancreas	2	.3	0	0	2	.3
Prostate	45	7.1	0	0	45	7.4
Sarcoma	4	.6	0	0	4	.7
Upper GI	58	9.1	2	8.0	56	9.2
Other Health Problems*						
Type 2 Diabetes	112	17.6	5	20.0	107	17.5
Hyperlipidemia	241	37.8	10	40.0	231	37.7
Hypertension	272	42.7	7	28.0	265	43.3
Heart Failure	21	3.3	0	0	21	3.4
Stroke	16	2.5	2	8.0	14	2.3
Heart Disease or CAD	52	8.2	2	8.0	50	8.2
Chronic Kidney Disease	43	6.8	1	4.0	42	6.7
Malnutrition	48	7.5	2	8.0	46	7.5

Values are presented as n (%) unless otherwise specified. Percentages are calculated within each column. Categories marked with an asterisk do not total 100%. Age is presented as mean ± standard deviation (SD) and is not reported as n or %. Disability status reflects the proportion of patients with documented disability in the medical record, with percentages calculated within each category (total, FI, FS). Insurance type includes both primary and secondary coverage and will not equal 100%. For comorbid conditions, patients may have more than one diagnosis and so this category will not total 100%. Other categories without an asterisk total 100%, although may not sum exactly due to rounding.*

Cancer categories reflect the primary diagnosis documented at the time of screening. "Blood and lymphatic system" includes leukemias, lymphomas, myelomas, and other related cancers. "Head and neck" include oral cavity, pharynx, larynx, nasal cavity, and other related cancers. "Upper GI" includes esophageal, gastric, and related cancers.

Hyperlipidemia includes diagnoses of hypercholesterolemia, dyslipidemia, or high cholesterol. Heart disease or coronary artery disease (CAD) includes myocardial infarction; atrial fibrillation was excluded. Chronic kidney disease (CKD) does not include acute kidney injury.

Abbreviations: SD, standard deviation; FI, food insecure; FS, food secure; CAD, coronary artery disease; CKD, chronic kidney disease; GI, gastrointestinal; HLD, hyperlipidemia; T2DM, type 2 diabetes mellitus; RUCA, Rural–Urban Commuting Area.

Notes: Other languages documented included American Sign Language (ASL), Bosnian, French, Korean, Laotian, Nepali, Spanish, and Tibetan. Other states of residence included Colorado, Connecticut, Florida, New Hampshire, Pennsylvania, and Texas.

Table 9:

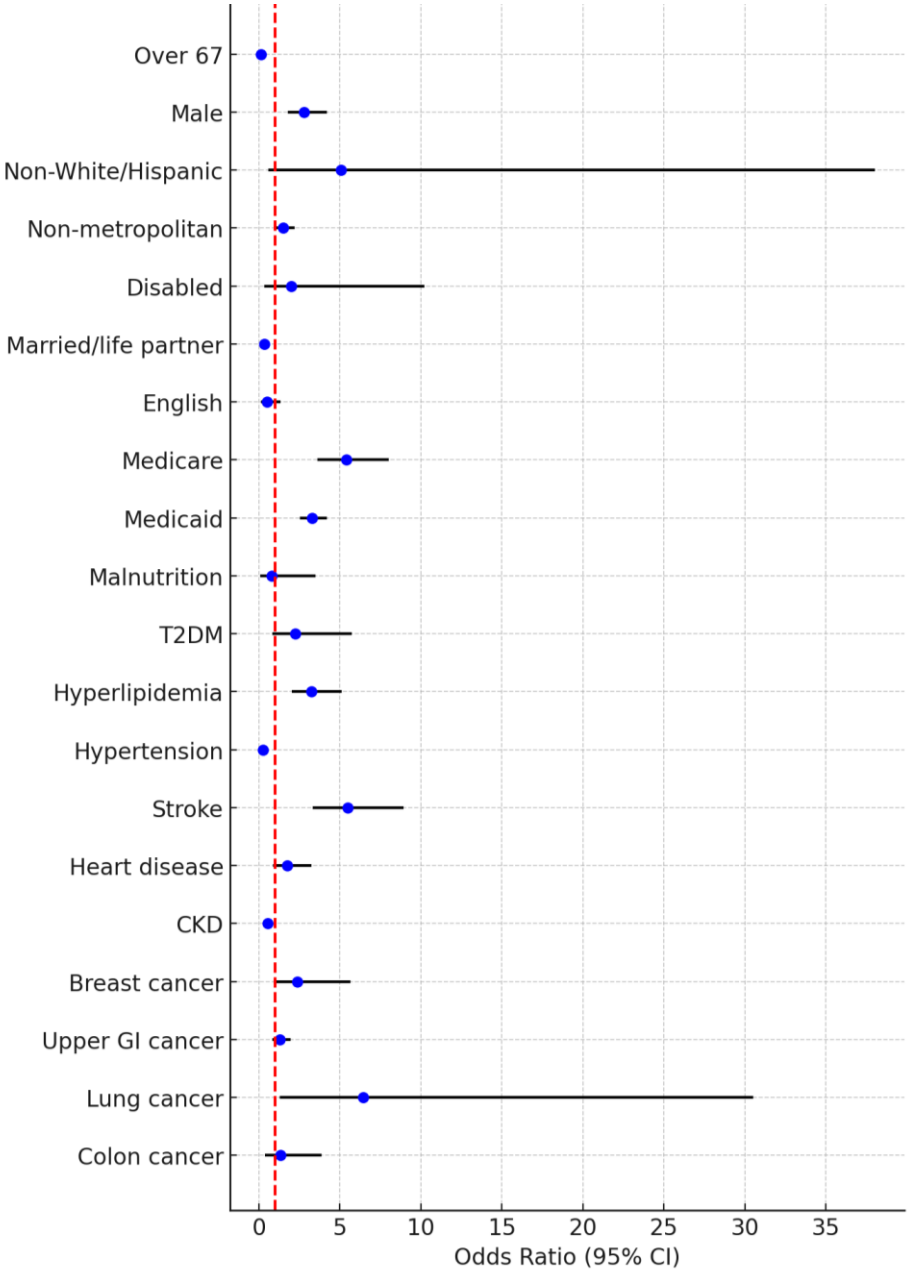
Multivariable Analysis of Factors Associated With Food Insecurity

Variable	Odds ratio	Robust Std. Error	z	*p*=	95% Confidence Interval	
Over 67	**0.134**	**0.015**	**-18.330**	**0.000**	**0.109**	**0.167**
Male	**2.766**	**0.552**	**5.100**	**0.000**	**1.871**	**4.089**
Non-White/Hispanic	5.066	5.206	1.580	0.114	0.676	37.964
Nonmetropolitan	**1.479**	**0.273**	**2.120**	**0.034**	**1.029**	**2.124**
Disabled	2.002	1.658	0.840	0.402	0.395	10.147
Married or life partner	**0.310**	**0.053**	**-6.890**	**0.000**	**0.222**	**0.432**
English	0.498	0.233	-1.490	0.136	0.199	1.245
Medicare	**5.402**	**1.056**	**8.630**	**0.000**	**3.682**	**7.926**
Medicaid	**3.276**	**0.375**	**10.360**	**0.000**	**2.617**	**4.102**
Malnutrition	0.777	0.585	-0.340	0.737	0.177	3.403
Type 2 Diabetes	2.254	1.054	1.740	0.082	0.901	5.635
Hyperlipidemia	**3.245**	**0.723**	**5.280**	**0.000**	**2.097**	**5.023**
Hypertension	**0.260**	**0.028**	**-12.650**	**0.000**	**0.211**	**0.321**
Stroke	**5.490**	**1.329**	**7.040**	**0.000**	**3.417**	**8.822**
Heart disease	1.721	0.529	1.760	0.078	0.941	3.145
Chronic Kidney Disease	**0.535**	**0.096**	**-3.490**	**0.000**	**0.376**	**0.760**
Breast Cancer	2.348	1.032	1.940	0.052	0.992	5.557
Upper GI Cancer	1.303	0.240	1.440	0.151	0.908	1.868
Lung Cancer	**6.443**	**5.101**	**2.350**	**0.019**	**1.365**	**30.415**
Colon Cancer	1.315	0.710	0.510	0.612	0.456	3.790

Notes. Odds ratios (OR) and 95% confidence intervals (CI) are presented from the mixed logit random effects model. Bolded variables indicate statistical significance ($p < 0.05$).

Figure 7:

Predictors of Food Insecurity Multivariable Model



Notes. Significant variables are those where the confidence interval (black line) does not cross the dotted red line at OR = 1. Dots to the right of the line indicate increased odds of FI, while dots to the left indicate decreased odds.

Discussion:

The prevalence of FI among cancer patients at UVMC was 3.9%, notably lower than national, state, and previously reported cancer-specific rates. Despite this low overall prevalence, the odds of FI were significantly higher among men, those residing in nonmetropolitan areas, patients with Medicaid or Medicare coverage, and those with lung cancer, hyperlipidemia, or stroke. Conversely, the odds of FI were significantly lower among those above the age of 67, those married or partnered individuals, and patients with hypertension or CKD.

The FI rate identified in this study was lower than the Vermont average of 12.2% in 2023 (61). This difference may be partly explained by the age of diagnosis, as cancer incidence increases with age (62), while FI prevalence can be lower among older adults (63). Another possibility is that individuals facing greater socioeconomic hardships, including FI may be less connected to care (64) and therefore less likely to receive a cancer diagnosis or undergo treatment. More financially secure patients may also preferentially seek care at the academic center rather than at smaller rural hospitals closer to home. The sample further lacked racial and ethnic diversity, even compared with Vermont's overall demographics (65), which is notable given the socioeconomic disparities experienced by many racial and ethnic minority groups. Vermont's relatively strong social safety nets and rural health programs may contribute to the lower FI rate observed compared with other studies on this topic.

Even within this predominantly White and rural sample, subgroup differences were evident. Adults aged 67 years or older were less vulnerable to FI at diagnosis, suggesting that younger individuals face greater risk. This pattern may reflect the wealth gap between younger and older adults (66) as well as caregiving responsibilities (38), which may exacerbate vulnerability when later confronted with cancer-related costs. Contrary to previous national research finding women more likely to be food insecure (67), our results indicated men were at greater risk, which could warrant

further investigation. Consistent with prior studies (63), those who were not married or life partnered were also more likely to experience FI. Enrollment in Medicaid or Medicare was also consistent with prior studies finding a strong association with FI (1); this finding is concerning as it may highlight that existing public insurance programs are not enough to prevent FI. Similar to national data showing FI to be highest in rural regions and lowest in suburban areas (63), our study found non-metropolitan residence to be a significant predictor of FI. Elevated FI rates among patients with lung cancer were expected, given the shared risk factors with smoking (68), and the higher incidences of lung cancer among low SES individuals (69).

FI may also arise from non-financial barriers, including physical limitations related to illness or treatment, transportation challenges, residence in food deserts, and social isolation—factors that are seldom captured by commonly used measurement tools. In a study that assessed physical FI, 25.0% of older adults had physical difficulty accessing food but were not living in economically food insecure households (13). Physical access barriers may be particularly concerning for patients who live alone, especially in rural areas where community and healthcare resources are more limited.

Implications for future research could be assessing FI at various points during cancer survivorship and assessing the long-term impact of FI. The clinical and public health implications of these findings include building and maintaining partnerships between the clinical care team and food-is-medicine programs in the community that can provide supportive services. In addition to strengthening FI screening among high-risk groups and ensuring that populations at risk of underdiagnosis are not overlooked. While many factors in the literature are known predictors of FI status (such as Medicaid/Medicare), several of our results are quite new and novel – particularly men and single un-married individuals. Other clinical and public health interventions could include targeted support for younger and single-person households, expansion of screening tools to capture physical access barriers, and stronger referral pathways to social services are justified in meeting patient needs.

This study has several limitations. The small number of FI cases limited statistical power, and the cross-sectional design limits causal inference. Data entry was conducted by a single individual, introducing the potential for error. Additionally, the screening tool measured only financial aspects of FI, without capturing physical or social barriers. Marginalized patients were also underrepresented. Despite these limitations, the study has several notable strengths. This study adds to what is known by providing data on a predominantly rural population. The inclusion of diverse cancer types, linkage of screening data with electronic health records, and the large population of rural patients enhance both the novelty and relevance of these findings.

Conclusion/Implications:

Although overall FI prevalence was lower than expected, FI remains a concern for identifiable high-risk subgroups. Early identification and intervention may be especially critical in rural health systems, where resources are limited and travel barriers are common. Future research should assess longitudinal changes in FI during treatment and explore non-financial mechanisms affecting food access.

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CHAPTER 5: CONCLUSION

This thesis investigated the relationship between FI and cancer from multiple perspectives. Chapter 1 situated FI within the broader food system. Chapter 2 applied a food systems approach, applying the FAO's four domains of food security, to illustrate how oncology patients may experience FI. Chapter 3 presented a systematic literature review, which found FI prevalence among cancer patients to vary widely across studies but to disproportionately impact lower-income, younger, and racially/ethnically minoritized groups. This review also found non-financial mechanisms of FI to be underexplored. Chapter 4 examined FI prevalence and predictors at a largely rural northeastern hospital, finding overall rates lower than state and national averages, yet identifying key demographic and clinical subgroups at elevated risk. Collectively, these findings demonstrate that FI among oncology populations is complex and likely underrecognized. Recognizing limitations of existing tools, a set of proposed measurement items was compiled for future consideration in oncology settings in Appendix B. While not validated, these items map to FAO domains and may provide a foundation for tool development.

Research Implications: The systematic review highlights critical gaps in both measurement and intervention. Current USDA FI tools emphasize financial barriers, which likely lead to underestimates of FI among oncology patients. Without measures that also capture physical access, treatment-related limitations, and social support, the scope of FI in this population cannot be fully understood or addressed. Future research should prioritize the development and validation of oncology-specific tools that reflect the multidimensional nature of FI. Moreover, the challenges documented here are not exclusive to cancer patients; they may also affect other medically vulnerable populations, reinforcing the need for a broader systems-based approach to FI research and practice.

Clinical Implications: Findings from the UVMMC study provide valuable insight for both hospital and community stakeholders. While FI prevalence was lower than national and state levels, the identification of subgroups at higher risk suggests that FI may be undetected in clinical settings. This raises important questions about whether some patients—particularly those facing socioeconomic or geographic barriers—are being missed by the healthcare system altogether. As such, the study underscores the importance of targeted screening and resource connection, even in populations where FI prevalence appears relatively low.

Other clinical implications could include screening at diagnosis and throughout the cancer-care continuum, in addition to improved collaboration between disciples. Clarifying roles and relying on others expertise between dietitians and social workers (Shor, 2010), as well as collaborating with occupational and physical therapy to identifying barriers in food procurement and preparation challenges, may better address patient needs.

Hospital-based food pantries also represent a promising strategy, which can provide immediate food relief for underserved patients who face transportation barriers or may otherwise delay or forgo treatment because of cost (Gany et al., 2020). Similarly, improved public funding for Meals on Wheels could strengthen support for older adults with cancer, as the program currently relies on community contributions for approximately 70% of its annual budget (Meals on Wheels America, 2025a; Meals on Wheels America, 2025b).

Medical Nutrition Therapy (MNT) provided by a registered dietitian is effective in improving health outcomes (Moloney et al., 2025b; Movahed et al., 2020), however, coverage for MNT remains limited and varies considerably by state (Academy of Nutrition and Dietetics, 2025; Medicare, 2023). Similarly, although oral nutrition supplements are commonly recommended to mitigate nutrition challenges associated with cancer, reimbursement policies are inconsistent (Caccialanza et al., 2022). Improving coverage of these may better address patient needs.

Systems Context: This work situates FI at the intersection of multiple systems—the food system, the healthcare system, and the broader policy environment. FI among cancer patients is a downstream affect of larger structural inequities. While screening and treating downstream is great and recommended, understanding the larger systems this issue resides can help with pragmatic solutions upstream. This conclusion will wrap up by discussing income inequality, the housing crisis, and healthcare insecurity and their relationship to FI with possible government solutions.

Income inequality, which is highest in the US compared to its post-industrialized peers (*United Nations Humans Right Council*, May 2018), causes higher poverty rates and household debt (Piao et al., 2023), and is associated with food insecurity (Appendix A). Unfortunately, income inequality is also associated with adverse health incomes (Tan et al., 2021). Causes of income inequality include globalization, executive compensation increasing relative to the average worker, changes in technology, greater industry concentration, lower unionization rates, lower effective tax rates on higher incomes, and educational disparities (Polacko, 2021) Addressing this very large structural inequity from a government standpoint could include progressive tax reform, caps on market concentration, stronger labor protections, raising the minimum wage, and affordable higher education.

The housing crisis is another systematic issue influencing this topic. Since the 2020's the US has faced a growing shortage of housing (approx. 4.7million homes), increasing the cost of living and contributing to inflation in the US (U.S. Chamber of Commerce, 2025). Higher living expenses may decrease spending in other areas such as food or healthcare. Unfortunately, housing insecurity is associated with FI (Lee et al., 2021) making this another topic to address. Additionally, non-metropolitan areas generally have lower housing expenses (U.S. Department of Agriculture, Economic Research Service, 2013; DeSilver, 2024), which are areas with greater distances to grocery

stores (Dutko et al., n.d.). Policy responses could include expanding affordable housing infrastructure, reforming zoning laws, and subsidizing low-income rental assistance.

Healthcare insecurity is another systemic issue very related to this topic of FI among cancer patients. The US remains the only high-income country without universal healthcare, leaving unfortunately around 8% its population without insurance as of 2023 (Keisler-Starkey & Bunch, 2024). Medical expenses may divert household resources not allowing enough food. Research finds lack of health insurance coverage to be associated with FI (Park et al., 2024). Policy interventions could be expanding Medicaid, strengthening the Affordable Care Act protections, or moving to a different health coverage model (ex. universal coverage or a cost-sharing model).

In the mean time, food assistance programs such as SNAP, WIC, and the National School Lunch Program remain essential support for families experiencing FI. However, restrictive eligibility criteria and administrative hurdles limit their reach, suggesting the need for policy reforms that expand access and reduce bureaucratic barriers. Strengthening the charitable food system through sustained funding is also critical, as it continues to serve as a safety net for those excluded from federal programs. For patients with physical limitations, services such as Meals on Wheels and other home-delivered food programs play an indispensable role in maintaining food security and should be prioritized for investment and expansion.

Conclusion: Ultimately, this thesis demonstrates that addressing FI in cancer care requires more than financial support alone. Solutions must also address physical access barriers and confront the broader structural drivers of hardship embedded within healthcare and food systems. By positioning FI within this larger systems context, this work highlights opportunities for healthcare providers, community organizations, and policymakers alike to advance more equitable and comprehensive cancer care.

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Appendix A: Analysis of the Relationship Between Income Inequality and Food Insecurity in the United States, Craig Compton, Research Economist at Center for Economic Development and Business Research

Introduction: Food insecurity remains a persistent challenge in the United States, affecting millions of households each year. Numerous factors contribute to food insecurity, including economic conditions, unemployment, and public policy interventions. Among these factors, income inequality has been hypothesized as a significant determinant of food insecurity. This analysis examines the correlation between income inequality, as measured by the Gini index, and the prevalence of food insecurity in the United States from 1995 to 2023.

Data Sources:

- Gini Index: The Gini index, sourced from the U.S. Census Bureau via Statista, measures income inequality on a scale from 0 to 1, where 0 represents perfect equality and 1 indicates maximum inequality (U.S. Census Bureau, 2023).
- Food Insecurity Rates: Data on food insecurity, defined as the percentage of U.S. households experiencing difficulty securing adequate food due to financial constraints, is obtained from the U.S. Department of Agriculture (USDA) Economic Research Service (USDA ERS, 2023).

Methodological Approach: To assess the relationship between income inequality and food insecurity, a simple linear regression model is employed, using the Gini index as the independent variable (X) and the percentage of food-insecure households as the dependent variable (Y). The regression equation is specified as follows:

$$Y = \beta_0 + \beta_1 X + \epsilon$$

where:

- Y represents the percentage of food-insecure households,

- X is the Gini index,

- β_0 is the intercept,

- β_1 is the slope coefficient measuring the effect of income inequality on food insecurity,

- ϵ is the error term.

Estimation and Hypothesis Testing: The regression coefficients are estimated using the Ordinary Least Squares (OLS) method. The statistical significance of the relationship is evaluated using t-tests, with the following null hypotheses:

- H_0: $\beta_0 = 0$

- H_0: $\beta_1 = 0$

If the null hypothesis for β_1 is rejected at conventional significance levels (e.g., $p < 0.05$), it would indicate a statistically significant correlation between income inequality and food insecurity.

Model Evaluation: To assess the model's explanatory power and validity, the following statistical measures are examined:

- **R-squared (R^2):** Indicates the proportion of variance in food insecurity explained by income inequality.

- **F-test:** Evaluates the overall significance of the regression model.

- **Residual Analysis:** Checks for normality, heteroscedasticity, and autocorrelation to ensure the reliability of the model.

Results and Discussion: The regression analysis reveals a positive correlation between income inequality and food insecurity. Specifically, an increase of 0.01 in the Gini index is associated with a 0.5 percentage point rise in food insecurity rates. The model's R-squared value suggests that a substantial proportion of the variance in food insecurity is attributable to changes in income inequality. These findings align with existing literature indicating that higher levels of income disparity exacerbate economic hardships among lower-income households, making it more difficult for them to secure adequate food supplies (Gundersen & Ziliak, 2018).

Conclusion: This study provides empirical evidence supporting the hypothesis that rising income inequality contributes to increased food insecurity in the United States. Policy interventions aimed at reducing income inequality, such as progressive taxation, increased minimum wages, and expanded social safety net programs, may help mitigate food insecurity and improve overall well-being.

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Appendix B: Proposed Measurement Items for Cancer Care

While it is important to acknowledge the limitations of the HFSSM, it is equally important to consider potential alternatives. Below is a compilation of measurement items for a proposed food insecurity assessment tool in cancer care, which can serve as a foundation for further development and refinement. Any items marked with "unknown" indicate that, despite repeated attempts, no original published source could be identified. These items may have been generated by the author during graduate training or drawn from materials that could not be subsequently located. They are included as potential starting points for tool development but would require cognitive testing and validation prior to use in research or clinical practice. These items should not be considered validated measure unless the original source says so.

Table:

Mapping Food Insecurity Measurement Items to FAO Domains for Cancer Care

FAO Domain	Subdomain	Existing Item	Source	Proposed Adaptation
Availability	Home Food Production	For those with at-home food production, how has this been disrupted through treatment?	Proposed qualitative question	Same
Access	Economic Access	"During the past week, has your physical condition or medical treatment caused you financial difficulties?"	EORTC QLQ-C30[1]	Change timeframe to: "Since diagnosis, .."
Access	Economic Access	"Have those financial difficulties impacted your ability to buy food?"	Proposed	New item linking medical financial hardship to FI

Access	Economic Access	"Within the past 12 months, we worried whether our food would run out before we got money to buy more." "Within the past 12 months, the food we bought just didn't last and we didn't have money to get more."	Hunger Vital Sign[2]	If assessing the cancer timeline only change to "Since diagnosis,.."
Access	Transportation	"Do you have reliable transportation to access grocery stores outside your immediate neighborhood?"	Unsure	Same
Access	Transportation	"If you rely on public transportation, do you find it convenient to access grocery stores with good food options?"	Unsure	Same
Access	Transportation	"Do you feel safe walking or biking to the nearest grocery store?"	Unsure	Same
Access	Transportation	"Does your lack of transportation impact your ability to eat enough?"	Unsure	Same
Access	Food Deserts	"How far is the closest grocery store from your home?"	Unsure	Same
Access	Food Deserts	"How do you typically travel to the nearest grocery store?"	Unsure	Same
Access	Food Deserts	"What types of grocery stores are within walking distance of your home?"	Unsure	Same
Utilization	Physical Limitations	"If you had groceries available, would you be able to use them to prepare meals?" "Do you have reliable help with meal preparation?" "Are you able to get groceries into your home when you need them?"	Expanded Food Security Screener[3]	Same

Utilization	Physical Limitations	"By yourself and without using any special equipment, how much difficulty do you have going out to things like shopping, movies, or sporting events?" "By yourself and without using any special equipment, how much difficulty do you have lifting or carrying something as heavy as 10 pounds [like a sack of potatoes or rice]?" "By yourself and without using any special equipment, how much difficulty do you have preparing your own meals?"	NHANES (used in citation [4] to measure physical FI)	Same
Utilization	Daily Activities	"Does your health now limit you in these activities? (lifting/carrying groceries)"	RAND 36-Item Health Survey[5]	Add cooking/feeding options and follow-up "If you said yes, has the limitation in this activity decreased your food intake?"
Utilization	Anxiety about Preparation	"Do you worry about whether you will eat a good meal because you need help with grocery shopping or preparing food?" "Do you worry about whether you will eat a good meal because you need help preparing food or feeding yourself?"	Radimer/Cornell[6]	Same
Utilization	Energy Limitations	"I have lack of energy" Answers: Not at all, A little bit, Somewhat, Quite a bit, Very much.	FACT-G (Version 4)[7]	Add a follow up "Because of my physical condition, I have trouble meeting my nutritional needs"

Nutrition Insecurity	Quality & Health Concerns	Four-question Nutrition Security Module (N1–N4) In the last 12 months, (I/we) had to eat some foods that were not good for my health and well-being because (I/we) couldn't get other types of food. In the last 12 months, (I/we) knew there were things (I/we) should or should not eat for (my/our) health and well-being, but could not get healthful food. In the last 12 months, (I/we) worried that the food (I was/we were) able to eat would hurt (my/our) health and well-being. In the last 12 months, (I/we) had to eat the same thing for several days in a row because (I/we) didn't have money to buy other food.	Center for Nutrition & Health Impact[8]	Same

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Supplementary Materials

For the study *Mechanisms to Food Insecurity Following a Cancer Diagnosis: A Systematic Review and Implications for Measurement*

SM1: Search Strategy

Database	Subject Headings	Key Word Search (the same for all)	# of Results
Web of Science	Web of Science does not use subject headings, indexing terms, or MeSH terms, or equivalent. This data base will only use the key word search → https://www.webofscience.com/wos/woscc/summary/31374889-7bf4-443e-bf2e-83dc91fac7be-0126832475/relevance/1 (sample query link of what the right found →)	(cancer OR neoplasm OR oncology OR malignan* OR tumor* OR carcinoma* OR leukemia OR lymphoma OR sarcoma OR melanoma OR myeloma OR mesothelioma OR seminoma OR glioblastoma OR adenosarcoma OR androblastoma OR cholangioma OR endothelioma) AND ("food insecur*" OR "food secur*" OR "food insufficien*" OR "nutrition insecur*" OR "nutrition secur*" OR "nutrition insufficien*" OR "nutrient insecur*" OR "nutrient secur*" OR "nutrient insufficien*" OR "hunger" OR "food access" OR "food assistance" OR "food desert*" OR "food neglect" OR "food scarcity" OR "food deficit") Searching using the "topic" (not "all fields" or "abstract")	1031
Ovid version of Medline	The subject headings: Neoplasms OR Cancer Survivors AND Food Insecurity OR Food Security OR Food Deserts OR Hunger (Subject headings not available but that were for other databases: Cancer patient, cancer mortality,	(cancer OR neoplasm OR oncology OR malignan* OR tumor* OR carcinoma* OR leukemia OR lymphoma OR sarcoma OR melanoma OR myeloma OR mesothelioma OR seminoma OR glioblastoma OR adenosarcoma OR androblastoma OR cholangioma OR endothelioma).ti,ab,kw. AND ("food insecur*" OR "food secur*" OR "food insufficien*" OR "nutrition	1407

	oncology, food Assistance, and food access)	insecur*" OR "nutrition secur*" OR "nutrition insufficien*" OR "nutrient insecur*" OR "nutrient secur*" OR "nutrient insufficien*" OR "hunger" OR "food access" OR "food assistance" OR "food desert*" OR "food neglect" OR "food scarcity" OR "food deficit").ti,ab,kw.	
EMBASE	The subject headings: Malignant Neoplasm OR Cancer Patient OR Cancer Mortality OR Oncology AND Food Insecurity OR Hunger OR Food Desert OR Food Assistance OR Food Access	(cancer OR neoplasm OR oncology OR malignan* OR tumor* OR carcinoma* OR leukemia OR lymphoma OR sarcoma OR melanoma OR myeloma OR mesothelioma OR seminoma OR glioblastoma OR adenosarcoma OR androblastoma OR cholangioma OR endothelioma).ti,ab,kw. ("food insecur*" OR "food secur*" OR "food insufficien*" OR "nutrition insecur*" OR "nutrition secur*" OR "nutrition insufficien*" OR "nutrient insecur*" OR "nutrient secur*" OR "nutrient insufficien*" OR "hunger" OR "food access" OR "food assistance" OR "food desert*" OR "food neglect" OR "food scarcity" OR "food deficit").ti,ab,kw.	1643
CABI	Indexing Terms: Neoplasm AND Food Security OR Feeding Programs OR Nutrition Programmes OR Hunger OR Food Deserts OR Food Access (Subject headings not available but that were for other databases: cancer patient, cancer survivor, cancer mortality, oncology, and food assistance)	(cancer OR neoplasm OR oncology OR malignan* OR tumor* OR carcinoma* OR leukemia OR lymphoma OR sarcoma OR melanoma OR myeloma OR mesothelioma OR seminoma OR glioblastoma OR adenosarcoma OR androblastoma OR cholangioma OR endothelioma) AND ("food insecur*" OR "food secur*" OR "food insufficien*" OR "nutrition insecur*" OR "nutrition secur*" OR "nutrition insufficien*" OR "nutrient insecur*" OR "nutrient secur*" OR "nutrient insufficien*" OR "hunger" OR "food access" OR "food assistance" OR "food desert*" OR "food neglect" OR	302

		"food scarcity" OR "food deficit") "All fields" used	
CINAHL	Subject Headings: Neoplams OR "Cancer Patients" OR "Cancer Survivors" OR Oncology AND "Food Security" OR Hunger OR "Food Deserts" OR "Food Assistance" Using MH Exact Subject Heading (Subject headings not available but that were for other databases: cancer mortality and food access)	(cancer OR neoplasm OR oncology OR malignan* OR tumor* OR carcinoma* OR leukemia OR lymphoma OR sarcoma OR melanoma OR myeloma OR mesothelioma OR seminoma OR glioblastoma OR adenosarcoma OR androblastoma OR cholangioma OR endothelioma) AND ("food insecur*" OR "food secur*" OR "food insufficien*" OR "nutrition insecur*" OR "nutrition secur*" OR "nutrition insufficien*" OR "nutrient insecur*" OR "nutrient secur*" OR "nutrient insufficien*" OR "hunger" OR "food access" OR "food assistance" OR "food desert*" OR "food neglect" OR "food scarcity" OR "food deficit")	309

SM2: Extracted Details

I. Study Basics
   a. Study Title:
   b. Author(s):
   c. Journal:
   d. Publication Year:
   e. Type of study (ex. cross sectional, prospective, RCT, qualitative):
   f. Location:
   g. Study Objective:
   h. N =

II. Population and Setting Characteristics
   a. Population and setting (Cancer type(s), Cancer stage(s), Treatment phase (e.g., pre-treatment, active treatment, post-treatment, survivorship), Time since diagnosis, Age, range/mean age, Gender composition, Race/ethnicity, Income level / socioeconomic status, Other relevant demographics (e.g., disability, SNAP participation):

b. Underserved or Low-Resource Clinical Setting? For example, FQHC (federally qualified health center), IHS-referred patients (Native American, rural, public insurance), urban safety-net hospital. Yes or no?
c. Representative/ Generalizability:
d. National Representative? Yes or No

III. Food Insecurity Measurement
a. Food Insecurity Measurement Tool (ex. USDA 6-item, 10-item, 2-item Hunger VitalSign):
b. Timing of Food Insecurity Measurement (at dx, during tx, post tx, etc):
c. Type of Food Insecurity Captured (financial, physical, or both) (list pathway 1 or pathway 2):
d. Food Insecurity Prevalence %:
e. Change in FI over time (if longitudinal):

IV. Mechanism of FI
a. Evidence of Financial Mechanisms (ex. financial toxicity, medical debt, loss of income, cost of treatment, forgoing care):
b. Evidence of Non-Financial Mechanisms (ex. the physical environment such as food deserts, the person being physically unable to prepare food, fatigue, treatment side effects, transportation limitations, functional status):
    i. Mechanism measurement tools (if applicable, e.g., PROMIS, ADLs):

V. Pilot/RTC Section
a. Intervention Details for Pilot programs of RTC (Intervention description, comparator (if any), intervention duration, targeted mechanism (financial? physical? both?), food insecurity outcome results (pre-post):

VI. Results
a. Study Findings (Key findings related to food insecurity, key findings related to mechanisms, subgroup differences (e.g., by SES, treatment stage), reported limitations, author conclusions):
b. Other Outcomes (include measurement tools, this could be housing)
c. Optional, Quotes:

VII. Quality Related Notes
a. Bias Quality Assessment Score (+, N, -):
b. Authors limitations:
c. Limitations from our perspective and any additional commentary

SM3: A modified Version of the Academy of Nutrition and Dietetics Quality Criteria Checklist Bias Quality Assessment

Relevancy Questions
1. Would implementing the studied intervention or procedure (if found successful) result in improved outcomes for the patients/clients/population group? (N/A for some Epi studies)
2. Did the authors study an outcome (dependent variable) or topic that the patients/clients/population group would care about?
3. Is the focus of the intervention or procedure (independent variable) or topic of study a common issue of concern to dietetics practice?
4. Is the intervention or procedure feasible? (NA for some epidemiological studies)

Validity Questions
1. Was the research question clearly stated?
    1.1. Was the outcome(s) (dependent variable(s)) clearly indicated?
    1.2. Were the target population and setting specified?

2. Was the selection of study subjects/patients free from bias?
    2.1. Were inclusion/exclusion criteria specified (e.g., risk, point in disease progression, diagnostic or prognosis criteria), and with sufficient detail and without omitting criteria critical to the study?
    2.2. Were health, demographics, and other characteristics of subjects described?
    2.3. Were the subjects/patients a representative sample of the relevant population?

3. Were study groups comparable?
    3.1 If cohort study or cross-sectional study, were groups comparable on important confounding factors and/or were preexisting differences accounted for by using appropriate adjustments in statistical analysis? (Sub-question not used (NA))
    NOTE: Criterion #3 is NA if only one group was studied, comparison groups were not constructed for analysis, and a comparison to a reference standard not made.

4. Was method of handling withdrawals described?
    4.1 Was the number, characteristics of withdrawals (i.e., dropouts, lost to follow up, attrition rate) and/or response rate (cross-sectional studies) described for each group? (Follow up goal for a strong study is 80%.)
    4.2 Were all enrolled subjects/patients (in the original sample) accounted for?

6. Were intervention/therapeutic regimens/exposure factor or procedure and any comparison(s) described in detail? Were intervening factors described?
    6.1 In observational study, were interventions, study settings, and clinicians/provider described?
    6.1. Was the amount of exposure and, if relevant, subject/patient compliance measured?

7. Were outcomes clearly defined and the measurements valid and reliable?
    7.2. Were nutrition measures appropriate to question and outcomes of concern?
    7.3. Were the observations and measurements based on standard, valid, and reliable data collection instruments/tests/procedures?

7.5. Was the measurement of effect at an appropriate level of precision?
7.6. Were other factors accounted for (measured) that could affect outcomes?
7.7. Were the measurements conducted consistently across groups?

8. Was the statistical analysis appropriate for the study design and type of outcome indicators?
8.1. Were statistical analyses adequately described and the results reported appropriately?
8.2. Were statistics reported with levels of significance and/or confidence intervals?
8.3. Were adequate adjustments made for effects of confounding factors that might have affected the outcomes (e.g., multivariate analyses)?
8.4. Was clinical significance as well as statistical significance reported?

9. Are conclusions supported by results with biases and limitations taken into consideration?
9.1. Is there a discussion of findings?
9.2. Are biases and study limitations identified and discussed?

10. Is bias due to study's funding or sponsorship unlikely?
10.1. Were sources of funding and investigators' affiliations described?
10.2. Was there no apparent conflict of interest?

SM4. Bias Quality Assessment Scoring

	Anderson-Buettner 2024	Aziz-Bose 2024	Bona 2015	Bona 2016	Evans 2023	Garcia 2018	Hallgren 2023	Hao 2024	Koblitz 2024	Lin 2024	Luo 2023	McDougall 2024	McDougall 2020	Rosenberg 2024	Shi 2023	Valenzuela 2023	Valero-Elizondo 2021	Vaudin 2022	Zheng 2020a	Zheng 2023	Zheng 2020b
Overall Quality Rating	N	+	N	N	+	+	+	N	+	+	N	N	+	+	+	N	+	+	+	+	+
Relevancy Q's	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
VQ 1	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
VQ 2	N/A	Yes	No	No	Yes	Yes	Yes	No	Yes	Unsure	Yes	Unsure|No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
VQ 3	Yes	Unsure|N/A	Unsure|N/A	Unsure|N/A	Yes	Yes	Yes	N/A|yes	Yes	Yes	N/A	No|unsure	Yes	Unsure	Yes	N/A	Yes	Yes	Yes	Yes	Yes
VQ 4	Yes	Yes |No	Yes	No	Yes	Yes	N/A	Yes	N/A	Yes	Yes	Yes|No	Yes	Yes	Yes	Yes	N/A	Yes|N/A	Yes|N/A	Yes|N/A	Yes|N/A
VQ 6	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes|No	Yes	Yes	Yes	Yes	Yes	N/A	Yes	Yes	Yes	N/A|Yes
VQ 7	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	No|Yes	Yes|Unsure	Yes	Yes	Yes	Unsure	Yes	Yes	Yes	Yes	Yes
VQ 8	N/A	No	No	No	Yes	Yes	Yes	No	Yes	Yes	No|Yes	No	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes
VQ 9	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
VQ 10	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes|unsure	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes. Relevancy Questions (RQs) 1–4 were averaged for a single score. RQ1 and RQ4 were frequently marked *N/A* because most included studies were cross-sectional. Validity Question 5 was not applicable to this review and was omitted (see SM3).

Each validity question contained multiple sub-questions (e.g., 1.1, 1.2). For clarity, results are summarized at the question level rather than showing sub-questions item by item. There was no perfect way to condense these results into single sub-scores (ex. Yes or No). Sub-questions often produced mixed responses (e.g., *Yes*, *N/A*, *Unsure*, *No* within the same question), making summary difficult. The values presented here represent a simplified overview, typically reflecting the most common response across sub-questions. For validity questions with statistical components, an overall No was assigned if any sub-question within that category was scored as No.

When two overall scores are shown in a cell, this indicates that the two independent reviewers differed in their assessment. The first score represents the first author's assessment, and the second represents the second reviewer's.

Rational on Demoting

Anderson-Buettner 2024: Purposive sampling of seven patients and four providers from a single cancer center may introduce selection bias and limits representativeness of Native American patients and clinicians.

Bona 2015: Potential selection bias by only including English-speaking families. No multivariate analysis for potential confounding variables.

Bona 2016: Potential selection bias with only English-speaking families included and only ~half of eligible families were approached due to staffing availability. Withdrawals not described (T1=99 participants and T2=93 participants). No multivariate analysis for potential confounding variables.

Hao 2023: Potential selection bias with Spanish-speaking patients being excluded, as well as only patients able to attend outpatient care being included (possibly excluding those with the highest unmet needs). SDOH tool relied on an internal scoring algorithm which was not independently validated. No multivariate analysis for potential confounding variables. Funding not described.

Luo 2023: While the survey tools were based on validated instruments, the adapted versions used were not formally revalidated. No multivariate analysis for potential confounding variables.

McDougall 2024: Small sample size N=14 (32% of intended participant number) which limited generalizability and statistical analysis. Study groups may not have been comparable; even though groups were randomized, the UC group had a much higher proportion of participants with disability at baseline (0% vs 67%) which may confound results. Of the 17 participants randomized, 14 completed the 3-month follow-up and it's not described who or why they dropped out. Due to the small sample formal statistical testing was not done.

Valenzuela 2023: Specific survey instruments not specified not allowing for assessment of valid measurement tools and outcomes. "Quantitative material hardship domains (housing, food, utility, and transportation insecurity) were assessed through survey items adapted from validated social risk screening tools." No statistical tests or multivariable analyses for the quantitative section.