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Association between Post-Diagnosis Dietary Quality and Mortality in Prostate Cancer Survivors: Insights from NHANES 2005-2018

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Abstract

Background: Limited and inconsistent evidence is available on the association between dietary quality and mortality in prostate cancer (PCa) survivors. The present study aimed to elucidate the association between dietary quality, measured by the Healthy Eating Index (HEI), and mortality outcomes in PCa survivors. **Methods:** We analyzed data from 460 PCa survivors, representing a population of 2.25 million, derived from the National Health and Nutrition Examination Survey (NHANES) between 2005 and 2018. The HEI-2020 total and component scores were calculated based on the 24-hour dietary recall interviews, and a qualified score indicates a higher diet quality. The Weighted Cox Proportional Hazards Models were employed to evaluate the association between HEI-2020 and mortality outcomes. **Results:** After adjusting for potential confounders, no significant association was observed between the total HEI-2020 score and all-cause, cancer-specific, or non-cancer mortality. As for the components, a qualified fatty acid score (indicating higher consumption of poly- and monounsaturated fatty acids), and a qualified added sugars score (indicating lower consumption) were associated with reduced risk of all-cause mortality (HR 0.64 and 0.54, 95%CI: 0.41 - 1.00 and 0.31 - 0.94, respectively) and cancer-specific mortality (HR 0.33 and 0.40, 95%CI: 0.14 - 0.79 and 0.17 - 0.92, respectively, all $P < 0.05$). Conversely, a qualified sodium score (indicating limited consumption) was associated with an increased risk of all-cause and non-cancer mortality (HR 1.81 and 2.25, 95%CI: 1.05 - 3.12 and 1.31 - 3.85, respectively). Additionally, a qualified green and beans score (indicating higher consumption) was associated with an increased risk of cancer-specific mortality (HR 2.18, 95%CI: 1.11 - 4.31). **Conclusions:** Higher HEI-2020 scores do not uniformly translate to a reduced mortality risk among PCa survivors, and recommendations should focus on balanced dietary habits that emphasize healthier fat sources and reduced added sugars intake to enhance

long-term survival and quality of life for this population. These results also highlight the need for further research with a larger sample size to develop tailored dietary assessments and recommendations for PCA survivors.

Keywords

Prostate Cancer, Cancer Survivors, Dietary Quality, Healthy Eating Index

1. Introduction

Prostate cancer (PCa), the second most prevalent cancer in men globally, was also the most frequently diagnosed cancer among males in 118 out of 185 countries worldwide [1]. In 2022, approximately 1.5 million new cases of PCa were diagnosed, representing 7.3% of all new cancer cases globally [1]. Thanks to advancements in early detection and treatment, long-term survival rates for PCa patients have significantly improved, with recent data showing that 97.5% of PCa patients survive for at least five years [2]. This has resulted in a burgeoning population of PCa survivors, with an estimated 3.5 million in the United States as of January 1, 2022 [3], presenting a substantial challenge for healthcare and policy sectors.

Lots of research has identified positive relationships between high-quality diets and improved mortality outcomes among cancer survivors. Diets are hypothesized to enhance survival by modulating insulin and glucose metabolism, strengthening immune function, regulating hormone metabolism, reducing inflammation, and inhibiting tumor growth and metastasis [4]-[7]. While previous studies have explored the diet-risk relationship for PCa incidence and progression, the post-diagnosis dietary impact on mortality among PCa survivors is less clear, with mixed results. A systematic review has indicated that smoking and the intake of whole milk or high-fat dairy products are correlated with an increased risk of PCa mortality. Conversely, engaging in physical activity and consuming between half to one glass of red wine daily have been linked to a reduced risk of PCa mortality. Studies on the consumption of vegetables, dietary fats, and processed meats have yielded inconclusive results regarding their association with all-cause and PCa-specific mortality, with most studies failing to identify significant associations among these variables [8] [9]. Furthermore, a recent study published in JAMA ONCOLOGY revealed that in men diagnosed with GG1 PCa undergoing active surveillance, higher adherence to the Dietary Guidelines for Americans (DGA) is associated with a lower risk of grade reclassification, particularly to GG3 or more significant disease [10]. This finding implies that enhanced dietary quality (DQ) could potentially slow cancer progression in PCa survivors, thereby improving their long-term outcomes.

The HEI serves as a tool to measure DQ, assessing both the overall diet and certain food components, and is used to evaluate alignment with the DGA [11]. The HEI-2020 comprises 13 components that reflect a healthy eating pattern. Each

component is scored based on intake relative to the DGA standards, providing a quantitative measure of DQ [11]. The HEI has been widely used in surveillance, epidemiological, and intervention studies to analyze DQ within populations [12]. However, while the HEI is a well-established measure for DQ in the general population, and a number of studies have examined the association between HEI scores and the incidence and progression of PCa [10] [13]-[15], to our knowledge, there is currently no other study have reported the relationship between HEI scores and mortality risk in PCa survivors.

With the growing number of PCa survivors, dietary recommendations that address their specific requirements are urgently needed. This study seeks to explore the relationship between DQ, as measured by the HEI-2020, and mortality among PCa survivors, to enhance clinical practice and inform public health policy.

2. Methods

2.1. Study Population

This study leveraged datasets from the National Health and Nutrition Examination Survey (NHANES) conducted between 2005 and 2018. NHANES is a nationally representative, continuous cross-sectional survey targeting the non-institutionalized civilian population of the United States, executed by the National Center for Health Statistics, which is part of the Centers for Disease Control and Prevention. The program has been conducted continuously since 1999, with data released biennially. Detailed descriptions of NHANES' data collection methods and procedures can be found elsewhere [16]. The NHANES protocol, along with the publicly released de-identified data, was reviewed and approved by the Ethics Review Board of the National Centre for Health Statistics (NCHS), and all participants provided written informed consent.

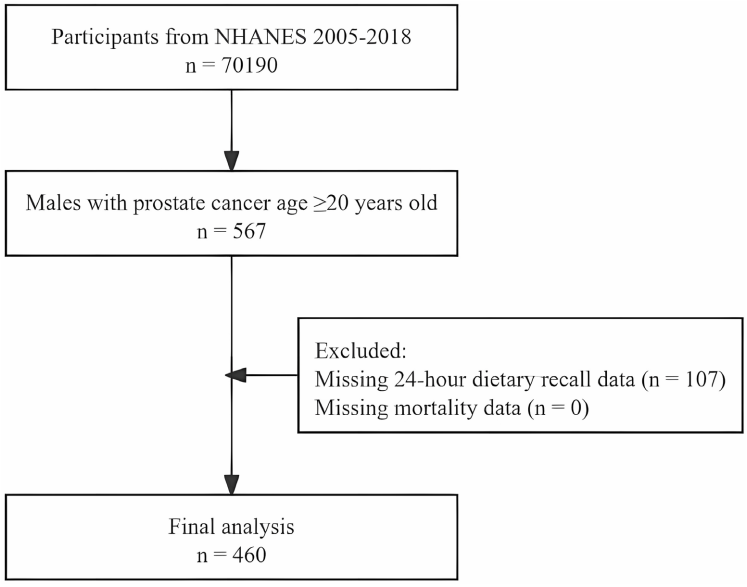

Figure 1. Flowchart of the study participants.

For this analysis, we included 567 adults aged 20 years and above who self-reported a prior diagnosis of PCa. The diagnosis was confirmed by participants' affirmative responses to the question, "Were you ever told by a doctor or other health professional that you had cancer or a malignancy of any kind?" Among the 567 individuals, 107 were excluded from the analysis due to incomplete dietary recall information. Ultimately, the analysis encompassed the data from 460 participants (**Figure 1**).

2.2. Dietary Assessment

Post-diagnosis dietary information was collected via two 24-hour dietary recall interviews, which were strategically scheduled across different days of the week and throughout the year to capture a comprehensive dietary profile. During these interviews, trained interviewers prompted participants to report on their food and beverage consumption within the past 24-hour period, with detailed accounts of quantities, recipes, and dining locations being recorded. The nutrient values were derived from the reported dietary intake, utilizing the United States Department of Agriculture Food and Nutrient Database for Dietary Studies as the analytical tool. The collected dietary data was subsequently utilized to calculate the total and component scores of the HEI-2020 [17].

2.3. Healthy Eating Index-2020

The HEI-2020 is a scoring system to evaluate the overall quality of dietary intake, designed to assess the extent to which the dietary habits of the U.S. population align with the 2020-2025 DGA. The index employs a density-based approach and is composed of 13 dietary components, divided into nine adequacy components (total fruits, whole fruits, total vegetables, greens and beans, whole grains, dairy, total protein foods, seafood and plant protein, and fatty acids) and four moderation components (refined grains, sodium, added sugars, and saturated fats). A higher total HEI-2020 score indicates a superior DQ, with a scale ranging from 0 to 100. For the adequacy components (*i.e.*, food components to encourage), higher scores reflect higher consumption, while for the moderation components (*i.e.*, food components to limit), higher scores indicate lower consumption. A total HEI score of 60 or above is considered to meet the dietary recommendations [18]. In this study, participants were classified into two groups according to their total HEI scores: unqualified (<60) and qualified (≥60). For individual HEI components, a score is regarded as qualified when it meets or exceeds 60% of the maximum score for that component.

2.4. Outcome Ascertainment

The primary endpoints of our study were all-cause mortality, cancer-specific mortality, and non-cancer mortality. Data regarding mortality and follow-up duration were sourced from the NHANES Public-Use Linked Mortality File, which integrates information from the NHANES and the National Death Index. A comprehensive

description of the linkage methodology has been previously described [19]. Prior research has confirmed the reliability of mortality ascertainment through the National Death Index. The 10th edition of the International Classification of Diseases (ICD-10) was used to categorize causes of death, with codes C00–C97 indicating cancer-specific mortality. The follow-up time was defined as the interval from the completion of the NHANES questionnaire (in months) until the occurrence of death from any cause or the conclusion of the follow-up period (December 31, 2019), whichever event came first.

2.5. Covariates assessment

We included various covariates that may affect the outcome, including age, age at PCa diagnosis, race/ethnicity, level of education, marital status, family poverty income ratio, smoking status, alcohol consumption, moderate or vigorous physical activity (MVPA), BMI status, diabetes, hypertension, and hyperlipidemia [20]. The time interval between diagnosis and study entry was calculated as the difference between the age at the time of the survey and their age at PCa diagnosis. The details of relevant definitions were shown in the Supplementary Method.

2.6. Statistical Analysis

To account for the complex sampling design and generate estimates that are representative at a national level, sample weights were applied in accordance with the NHANES analytical protocols. Demographic and baseline characteristics were presented based on the total HEI-2020 score classifications (unqualified and qualified). Continuous variables were expressed as weighted means with standard errors (SE), while categorical variables were presented as raw counts complemented by weighted percentages. For continuous variables that were normally distributed, the Student's t-test was employed, and for those with a non-normal distribution, the Kruskal–Wallis test was utilized. The chi-squared ($\chi 2$) test was used to compare categorical variables. The relationship between HEI scores and mortality risk was assessed using Cox proportional hazards regression models. The initial model (Model 1) was unadjusted. Model 2 was adjusted for age, race, marital status, educational level, family poverty income ratio, smoking status, alcohol use, BMI, hypertension, hyperlipidemia, diabetes, MVPA, and the time elapsed between diagnosis and study entry. The missing data were handled using multiple imputation methods. All statistical analyses were performed using R software (version 4.4.1), with the significance level set at a two-tailed P-value <0.05.

3. Results

3.1. Study Population Characteristics

As shown in Table 1, the study comprised a total of 460 PCA survivors, representing a weighted population of 2.25 million, with a weighted median age of 71.6 years. Among the participants, 75.7% were identified as Non-Hispanic White, and only 21.1% reported a BMI of normal range. Participants who achieved qualified

HEI-2020 scores exhibited a higher likelihood of being older (73.7 years vs. 71.6 years), having a normal BMI (30.4% vs. 21.1%), engaging in vigorous or moderate activity within the past week (67.1% vs. 49.6%), and a lower likelihood of having hypertension (68.2% vs. 77.1%). No statistically significant differences were observed in terms of educational level, marital status, income level, smoking status, alcohol use, diabetes, hyperlipidemia, or mortality categories between participants with qualified and unqualified total HEI scores.

Qualified rate of the total and component HEI-2020 scores were presented in Figure 2. Overall, 33.7% of the participants achieved a qualified total HEI-2020 score.

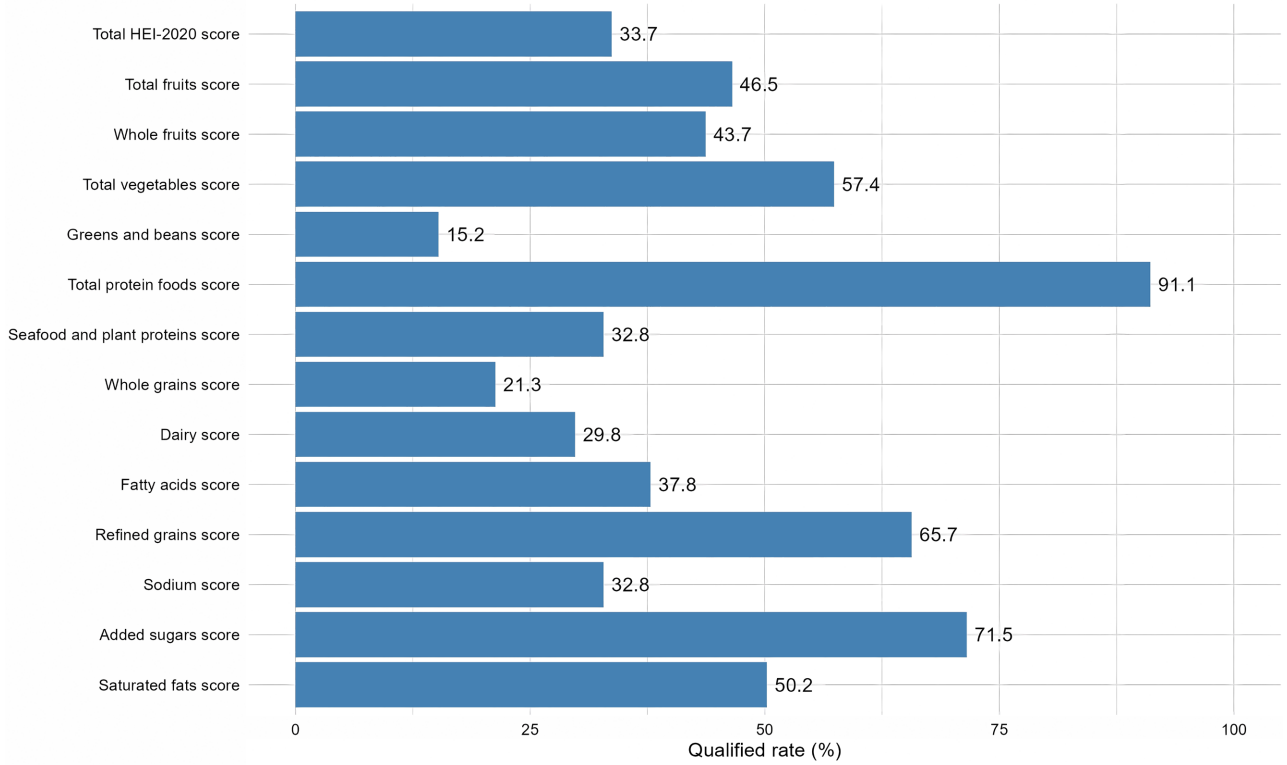

Figure 2. Qualified rate of the healthy eating index scores among prostate cancer survivors.

Table 1. Baseline characteristics of participants.

Variable	Overall (n = 460) N = 2,250,883†	Total HEI-2020 score		P-value
		Unqualified (n = 305) N = 1,575,548†	Qualified (n = 155) N = 675,335†	
Age, Mean (SE)	71.6 (0.6)	70.7 (0.8)	73.7 (0.7)	**0.007**
Age at diagnosis, Mean (SE)	63.9 (0.7)	63.3 (0.9)	65.5 (0.9)	**0.024**
Time between diagnosis and study entry, years, Mean (SE)	7.7 (0.4)	7.5 (0.5)	8.2 (0.8)	0.988
Follow-up time, months, Mean (SE)	68.4 (3.6)	66.1 (4.6)	73.8 (4.5)	0.196

Continued

Race, n (%)				**0.009**
Hispanic	49 (4.3)	36 (4.3)	13 (4.2)	
Non-hispanic white	243 (75.7)	156 (78.0)	87 (70.3)	
Non-hispanic black	145 (16.1)	102 (15.6)	43 (17.4)	
Other race	23 (3.9)	11 (2.1)	12 (8.1)	
Educational level, n (%)				0.347
Less than high school	101 (13.3)	80 (14.9)	21 (9.6)	
High school	96 (17.3)	67 (17.9)	29 (16.0)	
Greater than high school	263 (69.4)	158 (67.2)	105 (74.5)	
Marital status, n (%)				0.860
Married/Living with partner	321 (72.6)	212 (73.2)	109 (71.1)	
Widowed/divorced/separated	117 (24.5)	76 (23.7)	41 (26.3)	
Never married	22 (2.9)	17 (3.0)	5 (2.7)	
Family poverty income ratio, n (%)				0.614
<1.3	89 (12.5)	64 (13.8)	25 (9.4)	
1.3 - 3.49	206 (39.1)	139 (39.0)	67 (39.4)	
>=3.5	165 (48.4)	102 (47.2)	63 (51.2)	
Weight status, n (%)				**0.016**
Normal	112 (21.1)	65 (17.2)	47 (30.4)	
Underweight	5 (0.7)	5 (1.0)	0 (0.0)	
Overweight	197 (45.3)	132 (44.1)	65 (48.1)	
Obese	146 (32.8)	103 (37.6)	43 (21.5)	
Smoking status, n (%)				0.360
Never	177 (40.1)	107 (37.4)	70 (46.3)	
Ever	235 (51.8)	161 (53.4)	74 (48.0)	
Now	48 (8.1)	37 (9.2)	11 (5.6)	
Alcohol use, n (%)				0.097
Never	36 (6.0)	20 (4.1)	16 (10.3)	
Ever	123 (21.1)	93 (22.7)	30 (17.4)	
Now	301 (72.9)	192 (73.2)	109 (72.3)	
MVPA, n (%)	220 (49.6)	125 (42.0)	95 (67.1)	**0.002**
Diabetes, n (%)	135 (29.2)	95 (32.5)	40 (21.7)	0.081

Continued

Hypertension, n (%)	368 (77.1)	251 (80.9)	117 (68.2)	0.080
Hyperlipidemia, n (%)	350 (81.9)	237 (86.9)	113 (70.1)	**0.002**
Mortality, n (%)	149 (33.7)	102 (34.2)	47 (32.5)	0.830
Cancer mortality, n (%)	51 (13.1)	36 (13.9)	15 (11.2)	0.679
Non-cancer mortality, n (%)	98 (20.6)	66 (20.3)	32 (21.2)	0.882

HEI-2020, Health Eating Index-2020; MVPA, moderate or vigorous physical activity. Data were presented as weighted mean (standard errors) or unweighted numbers (weighted percentages). †Weighted population. *P*-value <0.05 was considered significant.

3.2. Relationship between HEI-2020 and All-Cause Mortality in PCa Survivors

After adjusting for confounders (model 2, Table 2), no significant relationship was found between total HEI-2020 scores and all-cause mortality, while significant relationships were observed for individual HEI components. PCa survivors with a qualified fatty acid score (indicating higher consumption of poly- and monounsaturated fatty acids, PUFAs and MUFAs) or a qualified added sugars score (indicating lower consumption) were at lower risk of all-cause mortality (HR 0.64 and 0.54, 95%CI: 0.41 - 1.00 and 0.31 - 0.94, respectively), whereas those with a qualified sodium score (indicating limited consumption) faced an increased risk of all-cause mortality (HR 1.81, 95%CI: 1.05 - 3.12).

Table 2. Association of dietary quality with all-cause mortality among prostate cancer survivors.

	Model 1		Model 2	
	HR (95%CI)	P-value	HR (95%CI)	P-value
Total HEI-2020 score				
Unqualified (<60)	Ref		Ref	
Qualified (≥60)	0.83 (0.48 - 1.46)	0.528	0.90 (0.52 - 1.56)	0.705
Adequacy components				
Total fruits				
Unqualified (<3)	Ref		Ref	
Qualified (≥3)	1.03 (0.60 - 1.76)	0.911	1.02 (0.64 - 1.61)	0.945
Whole fruits				
Unqualified (<3)	Ref		Ref	
Qualified (≥3)	1.50 (0.90 - 2.51)	0.118	1.44 (0.90 - 2.29)	0.130
Total vegetables				
Unqualified (<3)	Ref		Ref	
Qualified (≥3)	1.04 (0.53 - 2.07)	0.903	1.11 (0.68 - 1.82)	0.670

Continued

Greens and beans				
Unqualified (<3)	Ref		Ref	
Qualified (≥3)	1.62 (0.63 - 4.16)	0.315	1.61 (0.89 - 2.94)	0.119
Total protein foods				
Unqualified (<3)	Ref		Ref	
Qualified (≥3)	0.93 (0.35 - 2.44)	0.876	0.86 (0.37 - 1.99)	0.729
Seafood and plant proteins				
Unqualified (<3)	Ref		Ref	
Qualified (≥3)	1.35 (0.72 - 2.53)	0.353	1.37 (0.86 - 2.19)	0.189
Whole grains				
Unqualified (<6)	Ref		Ref	
Qualified (≥6)	1.03 (0.59 - 1.79)	0.925	0.85 (0.50 - 1.46)	0.561
Dairy				
Unqualified (<6)	Ref		Ref	
Qualified (≥6)	0.97 (0.55 - 1.71)	0.905	0.91 (0.52 - 1.60)	0.756
Fatty acids				
Unqualified (<6)	Ref		Ref	
Qualified (≥6)	0.48 (0.31 - 0.76)	**0.002**	0.64 (0.41 - 1.00)	**0.0497**
Moderation components				
Refined grains				
Unqualified (<6)	Ref		Ref	
Qualified (≥6)	1.18 (0.64 - 2.19)	0.591	1.20 (0.68 - 2.10)	0.535
Sodium				
Unqualified (<6)	Ref		Ref	
Qualified (≥6)	1.62 (0.97 - 2.72)	0.067	1.81 (1.05 - 3.12)	**0.032**
Added sugars				
Unqualified (<6)	Ref		Ref	
Qualified (≥6)	0.47 (0.25 - 0.88)	**0.019**	0.54 (0.31 - 0.94)	**0.031**
Saturated fats				
Unqualified (<6)	Ref		Ref	
Qualified (≥6)	0.87 (0.46 - 1.63)	0.668	1.01 (0.62 - 1.66)	0.960

HEI-2020, Health Eating Index-2020; HR, hazard ratio; CI, confidence interval. Model 1: unadjusted model; Model 2: adjusted for age, race, marital status, educational level, family poverty income ratio, smoking status, alcohol use, BMI, hypertension, hyperlipidemia, diabetes, moderate or vigorous physical activity, and time between diagnosis and study entry. *P*-value <0.05 was considered significant.

3.3. Relationship between HEI-2020 and Cancer-Specific Mortality in PCa Survivors

In the adjusted model (model 2, Table 3), no significant differences were observed between total HEI-2020 scores and cancer-specific mortality, while significant relationships were observed for individual HEI components. PCA survivors with a qualified fatty acid score (indicating higher consumption of PUFAs and MUFAs) or a qualified added sugars score (indicating lower consumption) were at lower risk of cancer-specific mortality (HR 0.33 and 0.40, 95%CI: 0.14 - 0.79 and 0.17 - 0.92, respectively), while those with a qualified green and beans score (indicating higher consumption) faced an increased risk of cancer-specific mortality (HR 2.18, 95%CI: 1.11 - 4.31).

Table 3. Association of dietary quality with cancer-specific mortality among prostate cancer survivors.

	Model 1		Model 2	
	HR (95%CI)	*P*-value	HR (95%CI)	P -value
Total HEI-2020 score				
Unqualified (<60)	Ref		Ref	
Qualified (≥60)	0.71 (0.25 - 2.02)	0.524	1.13 (0.54 - 2.37)	0.741
Adequacy components				
Total fruits				
Unqualified (<3)	Ref		Ref	
Qualified (≥3)	0.83 (0.27 - 2.53)	0.740	1.24 (0.61 - 2.53)	0.554
Whole fruits				
Unqualified (<3)	Ref		Ref	
Qualified (≥3)	1.29 (0.42 - 3.93)	0.657	1.09 (0.63 - 1.90)	0.749
Total vegetables				
Unqualified (<3)	Ref		Ref	
Qualified (≥3)	0.42 (0.15 - 1.15)	0.090	0.60 (0.28 - 1.26)	0.175
Greens and beans				
Unqualified (<3)	Ref		Ref	
Qualified (≥3)	3.03 (0.68 - 13.46)	0.146	2.18 (1.11 - 4.31)	**0.024**
Total protein foods				
Unqualified (<3)	Ref		Ref	
Qualified (≥3)	1.10 (0.30 - 4.07)	0.888	0.71 (0.21 - 2.39)	0.576
Seafood and plant proteins				
Unqualified (<3)	Ref		Ref	
Qualified (≥3)	1.94 (0.60 - 6.28)	0.271	1.29 (0.62 - 2.68)	0.492

Continued				
Whole grains				
Unqualified (<6)	Ref		Ref	
Qualified (≥6)	0.55 (0.19 - 1.63)	0.283	0.61 (0.19 - 1.91)	0.391
Dairy				
Unqualified (<6)	Ref		Ref	
Qualified (≥6)	0.74 (0.25 - 2.16)	0.584	1.03 (0.45 - 2.32)	0.952
Fatty acids				
Unqualified (<6)	Ref		Ref	
Qualified (≥6)	0.26 (0.12 - 0.59)	**0.001**	0.33 (0.14 - 0.79)	**0.013**
Moderation components				
Refined grains				
Unqualified (<6)	Ref		Ref	
Qualified (≥6)	1.20 (0.43 - 3.37)	0.725	0.91 (0.45 - 1.83)	0.784
Sodium				
Unqualified (<6)	Ref		Ref	
Qualified (≥6)	0.97 (0.33 - 2.81)	0.952	1.43 (0.63 - 3.27)	0.392
Added sugars				
Unqualified (<6)	Ref		Ref	
Qualified (≥6)	0.30 (0.10 - 0.92)	**0.036**	0.40 (0.17 - 0.92)	**0.031**
Saturated fats				
Unqualified (<6)	Ref		Ref	
Qualified (≥6)	1.27 (0.39 - 4.17)	0.696	1.10 (0.59 - 2.06)	0.769

HEI-2020, Health Eating Index-2020; HR, hazard ratio; CI, confidence interval. Model 1: unadjusted model; Model 2: adjusted for age, race, marital status, educational level, family poverty income ratio, smoking status, alcohol use, BMI, hypertension, hyperlipidemia, diabetes, moderate or vigorous physical activity, and time between diagnosis and study entry. *P*-value <0.05 was considered significant.

3.4. Relationship between HEI-2020 and Non-Cancer Mortality in PCa Survivors

As shown in Table 4, model 2, no significant differences were observed in total HEI-2020 score or component scores between groups, except for sodium. A qualified sodium score (indicating limited consumption) was associated with an increased risk of non-cancer mortality (HR 2.25, 95%CI: 1.31 - 3.85).

Table 4. Association of dietary quality with non-cancer mortality among prostate cancer survivors.

	Model 1		Model 2	
	HR (95%CI)	*P*-value	HR (95%CI)	P-value
Total HEI-2020 score				
Unqualified (<60)	Ref		Ref	
Qualified (≥60)	0.92 (0.48 - 1.77)	0.803	0.79 (0.37 - 1.69)	0.542
Adequacy components				
Total fruits				
Unqualified (<3)	Ref		Ref	
Qualified (≥3)	1.19 (0.69 - 2.03)	0.536	1.02 (0.60 - 1.72)	0.948
Whole fruits				
Unqualified (<3)	Ref		Ref	
Qualified (≥3)	1.66 (1.02 - 2.71)	**0.042**	1.31 (0.73 - 2.36)	0.366
Total vegetables				
Unqualified (<3)	Ref		Ref	
Qualified (≥3)	1.92 (0.98 - 3.78)	0.057	1.55 (0.83 - 2.89)	0.168
Greens and beans				
Unqualified (<3)	Ref		Ref	
Qualified (≥3)	0.94 (0.52 - 1.68)	0.828	0.91 (0.44 - 1.88)	0.803
Total protein foods				
Unqualified (<3)	Ref		Ref	
Qualified (≥3)	0.84 (0.23 - 3.06)	0.796	0.95 (0.32 - 2.83)	0.927
Seafood and plant proteins				
Unqualified (<3)	Ref		Ref	
Qualified (≥3)	1.05 (0.59 - 1.88)	0.867	0.99 (0.53 - 1.85)	0.969
Whole grains				
Unqualified (<6)	Ref		Ref	
Qualified (≥6)	1.39 (0.69 - 2.80)	0.352	0.98 (0.42 - 2.29)	0.962
Dairy				
Unqualified (<6)	Ref		Ref	
Qualified (≥6)	1.13 (0.56 - 2.28)	0.732	0.86 (0.48 - 1.54)	0.615

Continued				
Fatty acids				
Unqualified (<6)	Ref		Ref	
Qualified (≥6)	0.64 (0.35 - 1.15)	0.136	0.82 (0.45 - 1.50)	0.523
Moderation components				
Refined grains				
Unqualified (<6)	Ref		Ref	
Qualified (≥6)	1.17 (0.54 - 2.56)	0.691	1.34 (0.68 - 2.64)	0.391
Sodium				
Unqualified (<6)	Ref		Ref	
Qualified (≥6)	2.19 (1.26 - 3.80)	**0.005**	2.25 (1.31 - 3.85)	**0.003**
Added sugars				
Unqualified (<6)	Ref		Ref	
Qualified (≥6)	0.62 (0.31 - 1.25)	0.185	0.74 (0.34 - 1.64)	0.462
Saturated fats				
Unqualified (<6)	Ref		Ref	
Qualified (≥6)	0.68 (0.37 - 1.26)	0.222	0.72 (0.43 - 1.21)	0.211

HEI-2020, Health Eating Index-2020; HR, hazard ratio; CI, confidence interval. Model 1: unadjusted model; Model 2: adjusted for age, race, marital status, educational level, family poverty income ratio, smoking status, alcohol use, BMI, hypertension, hyperlipidemia, diabetes, moderate or vigorous physical activity, and time between diagnosis and study entry. *P*-value <0.05 was considered significant.

4. Discussion

The present study investigated the relationship between DQ as assessed by the HEI-2020 and mortality outcomes among PCa survivors using data from the NHANES from 2005 to 2018. Our findings suggest that a higher HEI-2020 score did not significantly correlate with mortality risk in PCa survivors. Additionally, paradoxical correlations were found in this population between an increased mortality risk and appropriate consumption of greens and beans.

This study did not identify a statistically significant association between the overall HEI-2020 score and mortality outcomes. To our knowledge, no other studies have reported the relationship between HEI scores of PCa survivors and mortality risk. Although previous research has found a significant negative correlation between HEI scores and all-cause mortality as well as cancer-specific mortality in the general population [21], and many studies have suggested a similar negative correlation in cancer populations [15] [22], we have not found a similarly significant relationship at this time. It is also important to highlight that, given the high

survival rate associated with PCa—recent statistics indicate that the 5-year survival rate has reached 97.5%. In the current study, the limitations imposed by the observation period (68.4 months) resulted in a relatively small number of observed deaths. Future investigations may benefit from an extended observation period and an increased number of mortality cases to better elucidate the relationship between HEI scores and mortality outcomes among this population.

This study found that patients who consumed sufficient PUFAs and MUFAs (with qualified fatty acid scores) after PCa diagnosis had a lower risk of all-cause and cancer-specific mortality, which is consistent with previous results. A number of prior studies have shown that the intake of PUFAs and MUFAs is significantly associated with a lower risk of mortality in PCa survivors [23]-[27], while excessive intake of saturated fatty acids is associated with a significantly increased mortality rate [28] [29]. Unsaturated fatty acids may slow disease progression and improve patient survival prognosis through their anti-inflammatory pathways [23]-[27]. Given the diversity of the PC survivor population and the multiple factors that can influence health outcomes, our findings should be interpreted with caution. While we have adjusted for several known lifestyle confounders (such as smoking, alcohol consumption, and physical activity), we recommend further research to further investigate other unmeasured lifestyle factors (such as stress levels and sleep patterns) and genetic susceptibility. These additional factors could provide a more comprehensive understanding of the role of fatty acids in PC survivor health.

This research revealed that PCa survivors with lower intake of added sugars face a reduced risk of all-cause and cancer-specific mortality. While there have been limited studies examining the link between added sugar consumption and mortality risk in PCa survivors, earlier prospective research has indicated that a high intake of sugar-sweeten beverages might elevate the risk of developing PCa [30], and hyperinsulinemic, as well as insulin-resistant indices were positively associated with risk of PCa progression [31]. It is hypothesized that there is an indirect connection between sugar consumption and cancer, potentially linked to obesity and metabolic syndrome. However, there may also be associations that are independent of obesity, possibly related to hormonal imbalances or chronic inflammation [30].

This study found that PCa survivors with higher greens and beans consumption have a higher risk of cancer-specific mortality. Due to the extremely limited evidence on this component, it is difficult for us to make comparisons. According to the HEI-2020 definition, the component "greens and beans" includes green vegetables, beans, peas, and lentils [11]. On the one hand, it is possible that certain compounds in beans, such as soy phytoestrogens, may adversely affect hormone-sensitive cancers like PCa due to their estrogenic properties. This hypothesis is supported by research indicating that phytoestrogens can alter hormone levels and potentially disrupt prostate cell fate and tissue homeostasis, contributing to cancer progression [32]-[34]. On the other hand, although previous studies have

suggested that a plant-based diet may be associated with a lower risk of developing PCa [35]-[38], accumulating evidence suggesting that it was lycopene or other tomato phytochemicals that play an important role in improving the incidence and prognosis of PCa [39]-[41]. However, the components "greens and beans" do not include tomato or other foods containing lycopene, which may be an important reason why we did not find any benefits for PCa survivors. Future research should comprehensively analyze the food types of PCa survivors to clarify the potential impact of different types of vegetables and beans on the prognosis of PCa.

While the HEI is a useful tool for assessing overall DQ, several limitations should be considered when interpreting its relevance for PC survivors. One key limitation is the generalizability of the HEI to specific populations, particularly cancer survivors, whose dietary needs may differ from the general population due to the effects of cancer treatment or post-treatment recovery. The HEI focuses on broad dietary patterns and does not account for individual nutrient intake or the specific dietary requirements that may arise from cancer-related conditions. Additionally, the HEI does not consider the potential impact of treatment-related dietary restrictions, which may significantly influence overall DQ and its impact on health outcomes. These factors should be kept in mind when interpreting our findings, and future studies may benefit from more tailored dietary assessments that take into account the unique needs of cancer survivors.

5. Limitations

Acknowledging the limitations of this research is essential for a comprehensive interpretation of the findings. The dependence on self-reported data regarding dietary introduces the possibility of recall bias, as participants may misreport or forget their food intake, which may compromise the accuracy of the results. Although we used a validated tool (the 24-hour dietary recall), which provides reliable estimates, recall bias remains a concern. Future studies may benefit from using more objective dietary assessment methods to reduce this limitation further. Moreover, the study's design did not allow for the incorporation of critical variables such as cancer stage and treatment modalities, including surgery, radiation, and chemotherapy, which could influence dietary effects and mortality in PC survivors. Future research should aim to include information on cancer stages and treatment modalities to better understand their role in the health outcomes of this population.

6. Conclusion

The current study found certain HEI-2020 components associated with mortality outcomes in PCa survivors, but the total HEI-2020 score was not correlated with all-cause, cancer-specific, or non-cancer mortality in this group. These findings challenge the applicability of the HEI-2020 for post-diagnosis DQ assessment for PCa survivors, and highlight the need for further research with a larger sample size to develop tailored dietary assessments and recommendations for this population.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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Supplementary Material

Supplementary methods

Race/ethnicity were classified as:

- Non-Hispanic White
- Non-Hispanic Black
- Asian American
- Mexican American
- Other.

Educational levels were classified as:

- Less than high school
- High school
- Greater than high school

Marital status was classified as:

- Married/living with a partner
- Widowed/divorced/separated
- Never married.

Family poverty income ratio was classified into:

- <1.3
- 1.3 to <3.5
- ≥3.5

Smoking status was classified as:

- Never
- Ever
- Now

Alcohol consumption status was classified into:

- Never
- Ever
- Now

Moderate or vigorous physical activity (MVPA) was defined as engaging in any vigorous or moderate activity within the past week.

Body-mass index (BMI) was computed as weight in kilograms divided by the square of height in meters, and categorized into three weight status:

- Normal (BMI 18.5 to <25)
- Underweight (BMI <18.5)
- Overweight (BMI 25 to <30)
- Obese (BMI≥30)

Diabetes diagnosis was established by meeting any of the following criteria:

- Self-reported doctor diagnosis of diabetes
- Glycohemoglobin HbA1c > 6.5%

Hypertension diagnosis was established by meeting any of the following criteria:

- A systolic blood pressure of ≥ 130 mmHg
- A diastolic blood pressure of ≥ 80 mmHg
- Current use of antihypertensive medication

Hyperlipidemia diagnosis was established by meeting any of the following criteria:

- Total cholesterol (TC) ≥ 200 mg/dL
- Triglycerides (TG) ≥ 150 mg/dL
- Low-density lipoprotein cholesterol (LDL-C) ≥ 130 mg/dL
- High-density lipoprotein cholesterol (HDL-C) ≤ 50 mg/dL
- Use of lipid-lowering medications