Dietary patterns, nutrients, and prostate cancer grade progression

Zhuo Tony Su, MD
Johns Hopkins University School of Medicine
Jack A. Campbell, MD
Johns Hopkins University School of Medicine
Mufaddal Mamawala, MBBS MPH
Johns Hopkins University School of Medicine
Patricia K. Landis, BA
Johns Hopkins University School of Medicine
Yuezhou Jing, MS
Johns Hopkins University School of Medicine
Bruce J. Trock, PhD MPH
Johns Hopkins University School of Medicine
Christian P. Pavlovich, MD
cpavlov2@jhmi.edu

Johns Hopkins University School of Medicine

Research Article

Keywords:

Posted Date: April 14th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-9397037/v1

Additional Declarations: The authors declare no competing interests.

Abstract

Background

Active surveillance has become established as the preferred initial management strategy for men with favorable-risk prostate cancer, avoiding harms of overtreatment. Emerging evidence suggests that stricter adherence to dietary guideline recommendations may lower risk of disease progression during surveillance. However, it remains unclear which specific dietary patterns and nutrients may be protective. Using prospective data from one of the largest, longest-running active surveillance cohorts, we assessed dietary patterns and nutrients for association with prostate cancer grade progression.

Methods

We included men diagnosed with grade group (GG) 1 prostate cancer undergoing active surveillance who prospectively completed a validated food frequency questionnaire at baseline. We evaluated each man's baseline alternate Mediterranean Diet (aMED), Dietary Approaches to Stop Hypertension (DASH) diet, and plant-based diet index (PDI) scores. We performed competing risk proportional hazards regression to test the diet index scores and specific food and nutrient intakes for association with any upgrading (to ≥GG2) and extreme upgrading (to ≥GG3) on a surveillance biopsy, adjusting for baseline clinicopathological prognostic factors and smoking history.

Findings:

We included 868 men. After median follow-up of 7.9 years (quartiles 4.5–11.6), 207 men experienced upgrading, including 61 with extreme upgrading. A higher baseline PDI score was associated with a lower risk of upgrading (p-trend for quintiles 0.02) and extreme upgrading (0.04). Neither aMED nor DASH score was associated with either upgrading outcome. Alcohol consumption was positively associated with upgrading (subdistribution hazard ratio 1.09, 95% confidence interval 1.002–1.19).

Interpretation:

In a prospective cohort of nearly 900 men with long-term follow-up, greater adherence to a plant-based dietary pattern was associated with a reduced risk of prostate cancer grade progression on active surveillance, including progression to GG3 or worse disease which mandates curative treatment. These results can inform evidence-based dietary recommendations for men with favorable-risk prostate cancer.

Introduction

In men, prostate cancer is the most commonly diagnosed cancer in 118 countries and the leading cause of cancer deaths in 52 countries.[1] There has been significant controversy regarding prostate cancer screening via prostate-specific antigen (PSA) testing, in part due to frequent detection of low-grade disease, leading to overdiagnosis, overtreatment, and treatment-related morbidity.[2,3] To reduce the

harms of overtreatment without compromising survival, active surveillance has become established as the preferred initial management strategy for men diagnosed with favorable-risk prostate cancer.[4] Many men pursuing active surveillance are highly motivated to seek lifestyle modifications to mitigate the risk of disease progression necessitating radical treatment. Recently, prospective evidence has emerged suggesting that greater adherence to dietary guideline recommendations may slow disease progression.[5,6] However, it remains unclear which specific dietary patterns and nutrients may be protective in early-stage prostate cancer.

To date, several randomized clinical trials have evaluated lifestyle interventions in the active surveillance population,[7-9] but an effective intervention for decreasing disease progression risk has yet to be identified. Most notably, in the Men's Eating and Living (MEAL) study, a behavioral intervention that increased vegetable consumption failed to decrease the risk of disease progression.[7] This trial was limited by short follow-up. Because favorable-risk prostate cancer tends to grow slowly, any diet-driven changes in cancer progression may require a long time to show effects. Therefore, it may be difficult to conduct randomized trials on diet in favorable-risk prostate cancer due to the long-term nature of diet-related effects, let alone the ethical and logistical challenges of controlling diet for an extended period. Given these challenges, we utilized longitudinal observational data from one of the largest and longest-running prospective prostate cancer active surveillance cohorts in the world to study the association between dietary patterns, nutrients, and disease progression.

Methods

Participants

This study follows the STrengthening the Reporting of OBservational studies in Epidemiology (STROBE) reporting guideline. Established in 1995, the Johns Hopkins active surveillance program is a prospective cohort of men diagnosed with favorable-risk prostate cancer managed with active surveillance.[10] For this study, we included men enrolled in the program who were diagnosed with grade group (GG) 1 prostate cancer between January 2005 and February 2017, underwent a confirmatory biopsy (typically within 18 months of the diagnostic biopsy) verifying no worse than GG1 disease, and who upon enrollment prospectively completed the Block 1998 Food Frequency Questionnaire (FFQ; NutritionQuest, Berkeley, California) concerning their usual dietary patterns.[11] Ethical approval for this study was obtained from our Institutional Review Board. Written informed consents were obtained from study participants.

Diet Indexes

Based on each man's FFQ responses, NutritionQuest calculated his daily intake of various foods, beverages, nutrients, and total calories. The calculated dietary components allowed the computation of each man's baseline alternate Mediterranean Diet (aMED) score,[12] Dietary Approaches to Stop Hypertension (DASH) diet score,[13] and Plant-based Diet Index (PDI) score,[14] validated indexes

measuring adherence to the Mediterranean, DASH, and plant-based dietary patterns, respectively (see **Supplemental Table 1** for the scoring algorithms). The Mediterranean diet is a heart-healthy dietary pattern emphasizing whole foods including fruits, vegetables, whole grains, legumes, nuts, seeds, and olive oil, with moderate fish and seafood while limiting red and processed meat.[12] The DASH diet focuses on reducing hypertension and promoting heart health by encouraging whole grains, fruits, vegetables, nuts, seeds, legumes, and low-fat dairy, while limiting sodium, red and processed meat, and added sugars.[13] Lastly, a plant-based dietary pattern is a flexible approach that prioritizes making plant-based foods (broadly, including whole and refined grains, fruits and fruit juices, vegetables including potatoes, nuts, seeds, legumes, and vegetable oil) the majority of one's daily caloric intake, while reducing animal products and processed foods.[14]

Outcomes and Statistical Analysis

We assessed two outcomes, any disease upgrading (to ≥GG2) and extreme upgrading (to ≥GG3) on a surveillance biopsy. We performed competing risk proportional hazards regression to assess the association between each of the baseline aMED, DASH diet, and PDI score and each of the upgrading outcomes, adjusting for established prognostic covariates at baseline including age (per year), race (Black versus non-Black race), PSA density (per increase of 0.1 ng/mL^2), number of positive biopsy cores, and maximum core involved with cancer (per increase of 10%) at diagnosis, use of multiparametric prostate magnetic resonance imaging before confirmatory biopsy (versus not), and smoking history (current or former smoker, versus never smoker).[5,10] Competing events for any upgrading included volume reclassification only on a surveillance biopsy triggering treatment, elective treatment, and death from non-prostate cancer causes; competing events for extreme upgrading additionally included upgrading to GG2 on a surveillance biopsy.[5,10] Consistent with prior studies, we categorized the aMED score (possible range: 0 to 9 points) in tertiles,[15,16] the DASH diet score (8 to 40 points) in quartiles,[17] and the PDI score (18 to 90 points) in quintiles.[18] Linear trends in the scores were assessed by treating the quantiles as a linear variable and using the median value for each quantile. Median value imputation was performed for participants with missing values for PSA density. We utilized the Benjamini–Hochberg procedure to control the false discovery rate (FDR) to 25% for testing the diet indexes simultaneously.

Dietary Components

Next, we evaluated individual dietary components for association with any upgrading and extreme upgrading, adjusting for the same baseline covariates and an FDR of 25% for testing the dietary components simultaneously. Tested dietary components, all evaluated as numerical variables, included daily intake of calories, five major food groups (i.e., fruits, vegetables, grains, dairy, and protein foods) and key subgroups (i.e., components of the diet index scores), added sugars, oils, solid fats, alcoholic drinks, tea and coffee, and sugar sweetened beverages (**Supplemental Table 2**). According to the Food Patterns Equivalents Database (FPED) defined by the United States Department of Agriculture (USDA), the five food groups, added sugars, oils, solid fats, and alcoholic drinks constitute the main food pattern

components,[19] and we followed the FPED definitions in evaluating these components. Furthermore, the food groups and subgroups were energy-adjusted and evaluated in standard units of measurement per 1,000 kilocalories. We evaluated daily intakes of tea and coffee (a component of the PDI score) and sugar sweetened beverages (a component of the DASH diet and PDI scores) in grams.

Nutrients

Lastly, we evaluated daily intakes of macro- and micro-nutrients (**Supplemental Table 3**) for association with any upgrading and extreme upgrading, adjusting for the same baseline covariates and an FDR of 25% for testing the nutrient variables simultaneously. The daily intake of each nutrient was energy-adjusted (per 1,000 kilocalories) and combined intake from foods and supplements where applicable. Data were analyzed from September 30 to November 30, 2025. All tests were two-sided and performed using Stata, version 19.0 (StataCorp LLC, College Station, Texas).

Results

Baseline Characteristics

A total of 886 men met the inclusion criteria. After excluding 18 with incomplete FFQ data, we included 868 for analysis. Their baseline characteristics are summarized in Table 1. The median age at diagnosis was 66 years. The majority (91%) self-identified as White; 350 (40%) reported smoking history at baseline. The estimated median daily energy intake was 1,693 kilocalories (standard deviation [SD] 684 kilocalories). The median baseline aMED score was 4 (SD 2.0), DASH diet score 24 (SD 4.3), and PDI score 54 (SD 6.5).

Table 1
Baseline characteristics of men diagnosed with grade group 1 prostate cancer managed with active surveillance (N = 868)

Baseline characteristic	**Participants**	***Missing data, No. (%)***
Year of diagnosis, median (quartiles)	2010 (2007 to 2013)	*0 (0)*
Patient age at diagnosis, median (quartiles), y	66 (61 to 69)	*0 (0)*
Race, No. (%)		*0 (0)*
Black	54 (6.2)	*N/A*
White	786 (90.6)	*N/A*
Other [a]	28 (3.2)	*N/A*
Total prostate-specific antigen (PSA) level, median (quartiles), ng/mL	4.7 (3.5 to 6.1)	*1 (0.1)*
Prostate volume, median (quartiles), mL	45 (35 to 60)	*1 (0.1)*
PSA density, median (quartiles), ng/mL^2	0.10 (0.07 to 0.14)	*2 (0.2)*
Positive biopsy cores at diagnosis, median (quartiles)	1 (1 to 2)	*0 (0)*
Maximum core involved with cancer at diagnosis, median (quartiles), %	5 (1 to 15)	*0 (0)*
Use of mpMRI before confirmatory biopsy, No. (%)	309 (35.6)	*0 (0)*
Body mass index, median (quartiles), kg/m^2	26.6 (24.4 to 29.2)	*0 (0)*
Current or former smoker, No. (%)	350 (40.3)	*0 (0)*
Daily caloric intake, median (quartiles), Kcal	1,693 (1,322 to 2,148)	*0 (0)*
Alternate Mediterranean Diet (aMED) score, median (quartiles) [b]	4 (3 to 6)	*0 (0)*
Dietary Approaches to Stop Hypertension (DASH) diet score, median (quartiles) [c]	24 (21 to 27)	*0 (0)*
Plant-based Diet Index (PDI) score, median (quartiles) [d]	54 (50 to 58)	*0 (0)*

Active Surveillance Outcomes

After a median follow-up of 7.9 years (quartiles 4.5–11.6 years), 207 men experienced any upgrading during active surveillance, including 61 with extreme upgrading. Median follow-up for men who did not experience upgrading was 6.3 years (quartiles 3.3–9.3 years). Sixty-seven men (8%) died, all from non-

prostate cancer causes; 166 (19%) withdrew or were lost to follow-up. The cumulative incidence of any upgrading was 14% (95% confidence interval [CI] 12%–17%) at 5 years from cancer diagnosis, 25% (95% CI 22%–28%) at 8 years, and 30% (95% CI 26%–34%) at 10 years; that of extreme upgrading was 4% (95% CI 3%–5%) at 5 years, 7% (95% CI 6%–10%) at 8 years, and 9% (95% CI 6%–11%) at 10 years (**Figure**).

Diet Indexes and Upgrading

After adjusting for the baseline covariates, a higher baseline PDI score was associated with significantly lower risks of any upgrading (*p*-value for linear trend 0.02) and extreme upgrading (*p*-value for linear trend 0.04) during active surveillance. The associations remained statistically significant after controlling for the FDR (Table 2). Compared to men in the lowest quintile of PDI score, men in the highest quintile of PDI score had a 43% reduction in the risk of any upgrading (subdistribution hazard ratio [SHR] 0.57, 95% CI 0.36–0.89) and a 55% reduction in extreme upgrading (SHR 0.45, 95% CI 0.20–0.99; see **Supplemental Table 4** for subgroup comparisons by PDI score and **Supplemental Figs. 1–2** for upgrading outcomes stratified by PDI score). Neither the baseline aMED nor DASH diet score was significantly associated with either upgrading outcome (Table 2).

Table 2

Association between dietary indexes assessed at baseline and prostate cancer upgrading to grade group (GG) ≥ 2 and extreme upgrading to ≥GG3 on a surveillance biopsy in men diagnosed with GG1 disease managed with active surveillance

Dietary index assessed at baseline [a]	Upgrade (≥ GG2)			Extreme upgrade (≥ GG3)		
	No. events	SHR (95% CI)	*p* for trend	No. events	SHR (95% CI)	*p* for trend
Alternate Mediterranean Diet (aMED) score			.31			.66
1st tertile: score of 0 to 3 (n = 330)	80	Reference		20	Reference	
2nd tertile: score of 4 to 5 (n = 291)	78	1.05 (0.78–1.42)		27	1.44 (0.81–2.54)	
3rd tertile: score of 6 to 9 (n = 247)	49	0.83 (0.58–1.19)		14	0.88 (0.44–1.75)	
Dietary Approaches to Stop Hypertension (DASH) diet score			.19			.32
1st quartile: score ≤ 21 (n = 235)	65	Reference		17	Reference	
2nd quartile: score of 22 to 24 (n = 225)	53	0.76 (0.53–1.08)		18	0.93 (0.48–1.80)	
3rd quartile: score of 25 to 27 (n = 207)	44	0.76 (0.52–1.11)		14	0.81 (0.40–1.63)	
4th quartile: score ≥ 28 (n = 201)	45	0.79 (0.54–1.15)		12	0.71 (0.34–1.49)	
Plant-based Diet Index (PDI) score			**.02†**			**.04†**
1st quintile: score ≤ 48 (n = 182)	46	Reference		16	Reference	
2nd quintile: score of 49 to 52 (n = 174)	44	0.89 (0.59–1.36)		13	0.74 (0.35–1.55)	
3rd quintile: score of 53 to 56 (n = 201)	50	0.82 (0.55–1.23)		13	0.57 (0.28–1.19)	
4th quintile: score of 57 to 59 (n = 140)	36	0.92 (0.59–1.45)		9	0.59 (0.25–1.36)	
5th quintile: score ≥ 60 (n = 171)	31	0.57 (0.36–0.89)		10	0.45 (0.20–0.99)	

Dietary Components, Nutrients, and Upgrading

After adjusting for the baseline covariates, higher daily energy-adjusted intakes of total grains (SHR 0.73, 95% CI 0.62–0.87)—including whole (SHR 0.68, 95% CI 0.49–0.96) and refined grains (SHR 0.73, 95% CI 0.58–0.92)—and potatoes (SHR 0.13, 95% CI 0.02–0.88) were associated with a reduced risk of any upgrading, while higher daily intake of alcohol (SHR 1.09, 95% CI 1.002–1.19) was associated an increased risk of upgrading. All of these associations remained statistically significant after adjusting for the FDR (Table 3).

Table 3

Association between daily intake of calories, food groups, and beverages at baseline and prostate cancer upgrading to grade group (GG) ≥ 2 and extreme upgrading to ≥GG3 on a surveillance biopsy in men diagnosed with GG1 disease managed with active surveillance

	Upgrade (≥ GG2)		**Extreme upgrade (≥ GG3)**	
	No. events/N: 207/868		**No. events/N: 61/868**	
Daily intake at baseline [a]	SHR (95% CI)	*p*	SHR (95% CI)	*p*
Total calories, per 1,000 Kcal	0.90 (0.73–1.11)	.33	0.96 (0.64–1.44)	.85
Total fruits and fruit juices [b]	0.96 (0.72–1.29)	.80	0.78 (0.37–1.64)	.51
Whole (intact) fruits [b]	0.95 (0.66–1.36)	.78	0.73 (0.24–2.21)	.58
Fruit juices [b]	1.00 (0.60–1.66)	.99	0.88 (0.30–2.57)	.81
Total vegetables and legumes [b]	1.10 (0.93–1.30)	.27	0.91 (0.63–1.32)	.61
Vegetables (excluding potatoes and legumes) [b]	1.14 (0.97–1.34)	.12	0.94 (0.65–1.36)	.75
Dark green vegetables [b]	1.39 (0.96–2.02)	.08	1.00 (0.43–2.33)	.99
Total red and orange vegetables [b]	1.20 (0.92–1.56)	.18	1.21 (0.77–1.92)	.41
Potatoes [b]	**0.13 (0.02–0.88)**	**.04†**	0.17 (0.01–2.84)	.22
Total grains [c]	**0.73 (0.62–0.87)**	**.0004†**	0.90 (0.65–1.25)	.53
Whole grains [c]	**0.68 (0.49–0.96)**	**.03†**	0.89 (0.54–1.48)	.65
Refined grains [c]	**0.73 (0.58–0.92)**	**.01†**	0.90 (0.57–1.43)	.65
Total protein foods [c]	1.05 (0.93–1.18)	.45	1.16 (0.93–1.45)	.19
Red and processed meat [c]	1.15 (0.90–1.46)	.26	**1.50 (1.02–2.19)**	**.04**
Seafood [c]	1.13 (0.89–1.43)	.31	1.33 (0.92–1.91)	.13

	Upgrade (≥ GG2)		Extreme upgrade (≥ GG3)	
	No. events/N: 207/868		No. events/N: 61/868	
Plant protein (nuts, seeds, legumes, and soy products) [c]	0.98 (0.84–1.14)	.77	0.96 (0.72–1.28)	.80
Nuts and seeds [c]	1.00 (0.85–1.16)	.96	1.01 (0.76–1.33)	.97
Legumes [c]	0.71 (0.35–1.42)	.33	0.62 (0.15–2.49)	.50
Soy products [c]	0.59 (0.22–1.58)	.29	0.02 (0.00–1.86)	.09
Total dairy [b]	0.87 (0.63–1.21)	.41	**0.50 (0.26–0.94)**	**.03**
Oils [d]	1.02 (0.99–1.04)	.20	1.03 (0.98–1.07)	.28
Solid fats [e]	1.00 (0.97–1.02)	.81	0.99 (0.94–1.04)	.70
Added sugars (caloric sweeteners) [f]	0.99 (0.96–1.02)	.57	0.95 (0.90–1.01)	.10
Alcohol [g]	**1.09 (1.002–1.19)**	**.045†**	1.13 (0.94–1.35)	.19
Tea and coffee [h]	0.99 (0.95–1.02)	.47	**0.93 (0.87–0.99)**	**.03**
Sugar sweetened beverages [i]	1.05 (0.97–1.14)	.22	0.98 (0.82–1.17)	.82

Higher daily energy-adjusted intake of red and processed meat (SHR 1.50, 95% CI 1.02–2.19) was associated with an increased risk of extreme upgrading; higher daily energy-adjusted intake of dairy (SHR 0.50, 95% CI 0.26–0.94) and higher daily intake of tea and coffee (SHR 0.93, 95% CI 0.87–0.99) were associated with a decreased risk of extreme upgrading. However, none of these associations with extreme upgrading remained statistically significant after adjusting for the FDR (Table 3).

Higher daily energy-adjusted intake of carbohydrates was associated with reduced risks of any upgrading (SHR 0.91, 95% CI 0.85–0.98) and extreme upgrading (SHR 0.86, 95% CI 0.74–0.99), with the association for any upgrading remaining statistically significant after the FDR adjustment. None of the other nutrients assessed were significantly associated with either upgrading outcome (Table 4).

Table 4

Association between daily energy-adjusted intake of nutrients at baseline and prostate cancer upgrading to grade group (GG) ≥ 2 and extreme upgrading to ≥GG3 on a surveillance biopsy in men diagnosed with GG1 disease managed with active surveillance

	Upgrade (≥ GG2)		**Extreme upgrade (≥ GG3)**	
	No. events/N: 207/868		**No. events/N: 61/868**	
Daily energy-adjusted intake at baseline	SHR (95% CI)	*p*	SHR (95% CI)	*p*
Sodium, per 1 g/1,000 Kcal	0.83 (0.50–1.39)	.49	1.57 (0.59–4.19)	.37
Carbohydrate, per 10 g/1,000 Kcal	**0.91 (0.85–0.98)**	**.01†**	**0.86 (0.74–0.99)**	**.03**
Total fat, per 10 g/1,000 Kcal	1.12 (0.95–1.32)	.16	1.20 (0.88–1.62)	.25
Saturated fatty acids (SFAs), per 10 g/1,000 Kcal	1.25 (0.78–2.00)	.35	1.08 (0.47–2.47)	.86
Polyunsaturated fatty acids (PUFAs), per 10 g/1,000 Kcal	1.38 (0.90–2.11)	.14	2.06 (0.95–4.48)	.07
Monounsaturated fatty acids (MUFAs), per 10 g/1,000 Kcal	1.20 (0.84–1.70)	.32	1.28 (0.64–2.54)	.48
Fatty acid ratio: (PUFAs + MUFAs)/SFAs	1.03 (0.81–1.30)	.82	1.21 (0.80–1.82)	.37
Calcium, per 100 mg/1,000 Kcal*	0.96 (0.91–1.02)	.21	0.89 (0.78–1.02)	.09
Zinc, per 10 mg/1,000 Kcal*	0.94 (0.80–1.09)	.39	0.82 (0.62–1.09)	.17
Folate, per 100 µg/1,000 Kcal*	0.98 (0.90–1.07)	.70	0.90 (0.77–1.05)	.19
Selenium, per 100 µg/1,000 Kcal*	0.75 (0.53–1.06)	.11	1.01 (0.62–1.63)	.98
Vitamin A, per 1 mg/1,000 Kcal*	1.01 (0.98–1.05)	.38	0.98 (0.91–1.05)	.48
Vitamin D, per 100 IU/1,000 Kcal*	0.99 (0.88–1.11)	.83	0.87 (0.74–1.03)	.11
Vitamin E, per 100 a-TE/1,000 Kcal*	0.97 (0.81–1.15)	.70	1.06 (0.80–1.41)	.69
Alpha-carotene, per 1 mg/1,000 Kcal	1.21 (0.89–1.65)	.22	1.20 (0.70–2.05)	.51

	Upgrade (≥ GG2)		Extreme upgrade (≥ GG3)	
	No. events/N: 207/868		No. events/N: 61/868	
Beta-carotene, per 1 mg/1,000 Kcal*	1.02 (0.97–1.07)	.44	0.97 (0.87–1.08)	.56
Cryptoxanthin, per 100 µg/1,000 Kcal	0.98 (0.78–1.23)	.88	0.76 (0.45–1.30)	.32
Lutein, per 1 mg/1,000 Kcal	1.06 (0.97–1.15)	.24	0.99 (0.82–1.20)	.94
Lycopene, per 1 mg/1,000 Kcal	1.00 (0.97–1.04)	.95	1.02 (0.96–1.08)	.53
Retinol, per 1 mg/1,000 Kcal	0.47 (0.13–1.69)	.25	0.19 (0.01–3.37)	.26
Provitamin A carotenoids, per 1 mg/1,000 Kcal	1.04 (0.99–1.11)	.14	1.02 (0.92–1.14)	.69
Gamma tocopherol, per 10 mg/1,000 Kcal	1.10 (0.86–1.40)	.47	1.52 (0.99–2.33)	.06
Genistein, per 1 mg/1,000 Kcal	0.99 (0.91–1.07)	.76	0.94 (0.80–1.11)	.46
Daidzein, per 1 mg/1,000 Kcal	0.99 (0.86–1.15)	.94	0.94 (0.71–1.24)	.65
Total isoflavones, per 10 mg/1,000 Kcal	1.02 (0.71–1.46)	.92	0.97 (0.53–1.78)	.92
Quercetin, per 10 mg/1,000 Kcal	0.86 (0.58–1.28)	.47	0.39 (0.14–1.09)	.07
Choline, per 100 mg/1,000 Kcal	1.39 (0.96–1.99)	.08	1.36 (0.69–2.69)	.38

Discussion

In a prospective cohort of nearly 900 men diagnosed with GG1 prostate cancer managed with active surveillance, long-term follow-up data suggested that greater adherence to a plant-based dietary pattern, as measured by the baseline PDI score, is associated with a reduced risk of prostate cancer grade progression on active surveillance, including extreme progression to GG3 or worse disease, which mandates curative treatment. To our knowledge, this is the first prospective study to identify an inverse association between plant-based diet adherence and prostate cancer grade progression on active surveillance. Our findings align with prior prospective studies assessing plant-based diet adherence in other populations. In men without prostate cancer at baseline, a higher PDI score is associated with a

lower incidence of fatal prostate cancer.[20] In men diagnosed with nonmetastatic prostate cancer, PDI score is inversely associated with disease progression, defined as cancer recurrence after primary treatment, secondary treatment, bone metastasis, or cancer-specific mortality.[18]

Our findings may help inform evidence-based dietary counseling for men diagnosed with favorable-risk prostate cancer. As more of these men are managed initially with active surveillance to avoid the harms of overtreatment,[21] effective dietary modifications may help to slow or prevent disease progression warranting curative treatment, thereby delaying or avoiding treatment-related morbidity. Furthermore, consuming a plant-based diet has other health benefits, including reduced risks of diabetes,[14] and cardiovascular morbidity and mortality.[22] These benefits are particularly meaningful in favorable-risk prostate cancer, where men are more likely to die from chronic diseases than prostate cancer.

Moreover, we identified specific dietary components associated with prostate cancer grade progression on active surveillance. In our study, carbohydrates were the only nutrient, and grains and potatoes—both rich in carbohydrates—were the only foods associated with a lower risk of upgrading. Several dietary components demonstrated a suggestive association (i.e. association deemed not statistically significant after adjusting for multiple hypothesis testing) with extreme upgrading, a much rarer event: carbohydrates and dairy both with a lower risk of extreme upgrading, and red and processed meat with an increased risk. Taken together, these findings suggest that consuming plant-based sources of carbohydrates and eating dairy instead of red and processed meat for proteins, consistent with an overall plant-based dietary pattern, may be associated with a reduced risk of prostate cancer grade progression on active surveillance. The existing epidemiological evidence on carbohydrates, dairy, meat, and prostate cancer risk has been modest and largely mixed,[23–26] with few derived from the active surveillance setting. Our findings suggest that the risk of developing Gleason pattern 4 prostate cancer in men with known Gleason pattern 3 cancer (which would increase the overall grade from GG1 to GG2 or higher) may be mitigated by a plant-based diet, and specifically by a diet rich in carbohydrates and grains. These results warrant validation in further studies.

Our results also add to a growing body of evidence suggesting limiting alcohol intake for men with prostate cancer, and a potentially beneficial effect of moderate caffeine consumption. In our cohort, we identified a positive association between alcohol intake and prostate cancer upgrading, as well as a suggestive inverse association between tea and coffee consumption and extreme upgrading. These results are consistent with meta-analyses reporting a positive dose-response relationship between alcohol intake and prostate cancer incidence,[27] and an inverse association between coffee consumption and prostate cancer incidence.[28] In a prior prospective cohort study of men on active surveillance, although no significant association was found for coffee consumption and upgrading in the overall cohort, moderate coffee intake was associated with a decreased risk of upgrading in a subgroup with a fast caffeine metabolizer genotype.[29]

Notably, our study also yielded multiple negative findings confirming results of previous dietary research in prostate cancer. Similar to the aforementioned MEAL study,[7] we found no association between vegetable intake and prostate cancer upgrading on active surveillance. In our analysis, no specific micronutrients, including antioxidants, vitamins, and minerals, were associated with upgrading, consistent with randomized trials showing no benefit of vitamin supplementations for prostate cancer prevention (e.g., SELECT).[30] Furthermore, in our cohort, adherence to the Mediterranean and DASH dietary pattern, assessed using the baseline aMED and DASH diet score, respectively, was not associated with a reduced risk of upgrading, validating prior prospective studies evaluating these dietary patterns in smaller active surveillance cohorts.[15,16] Compared to a plant-based dietary pattern which encourages a flexible, broad range of plant-based foods, the Mediterranean and DASH diets emphasize a narrower set of whole foods. Nonetheless, given their well-established cardiovascular benefits, these diets remain advisable for general health counseling. While the ability to detect associations between individual dietary components and prostate cancer upgrading can always be improved with an even larger sample size, our study's findings may more likely reflect that any potential protective effects of individual dietary components are smaller than those conferred by an overall plant-based dietary pattern.

Our study has several limitations. Dietary exposures were derived from baseline self-reported questionnaires, which are subject to measurement error and do not capture dietary changes over time. However, the prospective design reduced recall bias, and upgrading rates were similar between respondents and nonrespondents.[5] The cohort consisted predominantly of White men with low-volume GG1 disease at diagnosis, which may not be generalizable to all patients. Compared with active surveillance cohorts in other dietary studies, our institutional cohort underwent more intensive surveillance biopsies, was slightly older at diagnosis, and had relatively low body mass index and daily caloric intake at baseline, suggesting a healthy lifestyle and/or underreporting of energy intake. Our study is observational and inherently prone to residual confounding, including other lifestyle factors. However, given the long natural history of favorable-risk prostate cancer, designing a randomized controlled trial assessing the various dietary patterns in our study with long-term follow-up and strict adherence to assigned dietary interventions would be prohibitively challenging and costly. Thus, while imperfect, our results derived from this well-curated prospective cohort offer practical and informative evidence for dietary recommendations for men pursuing active surveillance.

Conclusion

In a longitudinal, prospective cohort study of men diagnosed with GG1 prostate cancer managed with active surveillance, higher adherence to a plant-based dietary pattern was associated with a lower risk of prostate cancer grade progression, including extreme progression to GG3 or worse disease, which mandates curative treatment. Increased alcohol consumption was associated with a higher risk of grade progression. As active surveillance is increasingly employed as the initial management strategy for men diagnosed with favorable-risk prostate cancer, our findings may help inform evidence-based dietary

recommendations for men seeking to mitigate their risk of disease progression, thereby delaying or avoiding treatment-associated morbidity and preserving quality of life.

Declarations

Funding: None

References

1. Bray F, Laversanne M, Sung H et al (2024) Global cancer statistics 2022: GLOBOCAN estimates of incidence and mortality worldwide for 36 cancers in 185 countries. CA Cancer J Clin 74(3):229–263. 10.3322/caac.21834
2. Roobol MJ, de Mansson VII (2025) European Study of Prostate Cancer Screening – 23-Year Follow-up. N Engl J Med 393(17):1669–1680. 10.1056/NEJMoa2503223
3. Andriole GL, Crawford ED, Grubb RL 3 et al (2009) Mortality results from a randomized prostate-cancer screening trial. N Engl J Med 360(13):1310–1319. 10.1056/NEJMoa0810696
4. Spratt DE, Srinivas S, Adra N et al (2025) Prostate Cancer, Version 3.2026, NCCN Clinical Practice Guidelines In Oncology. J Natl Compr Canc Netw 23(11):469–493. 10.6004/jnccn.2025.0052
5. Su ZT, Mamawala M, Landis PK et al (2024) Diet Quality, Dietary Inflammatory Potential, and Risk of Prostate Cancer Grade Reclassification. JAMA Oncol 10(12):1702–1706. 10.1001/jamaoncol.2024.4406
6. Lin PH, Burwell AD, Giovannucci EL et al (2025) Dietary Patterns in Prostate Cancer Prevention and Management: A Systematic Review of Prospective Cohort Studies and Randomized Clinical Trials. Eur Urol 88(6):571–588. 10.1016/j.eururo.2025.07.017
7. Parsons JK, Zahrieh D, Mohler JL et al (2020) Effect of a Behavioral Intervention to Increase Vegetable Consumption on Cancer Progression Among Men With Early-Stage Prostate Cancer: The MEAL Randomized Clinical Trial. JAMA 323(2):140–148. 10.1001/jama.2019.20207
8. Ornish D, Weidner G, Fair WR et al (2005) Intensive lifestyle changes may affect the progression of prostate cancer. J Urol 174(3):1065–1069 discussion 1069–70. 10.1097/01.ju.0000169487.49018.73
9. Wright JL, Schenk JM, Gulati R et al (2024) The Prostate Cancer Active Lifestyle Study (PALS): A randomized controlled trial of diet and exercise in overweight and obese men on active surveillance. Cancer 130(12):2108–2119. 10.1002/cncr.35241
10. Tosoian JJ, Mamawala M, Epstein JI et al (2020) Active Surveillance of Grade Group 1 Prostate Cancer: Long-term Outcomes from a Large Prospective Cohort. Eur Urol 77(6):675–682. 10.1016/j.eururo.2019.12.017

11. Boucher B, Cotterchio M, Kreiger N, Nadalin V, Block T, Block G (2006) Validity and reliability of the Block98 food-frequency questionnaire in a sample of Canadian women. Public Health Nutr 9(1):84–93. 10.1079/phn2005763
12. Fung TT, Rexrode KM, Mantzoros CS, Manson JE, Willett WC, Hu FB (2009) Mediterranean diet and incidence of and mortality from coronary heart disease and stroke in women. Circulation 119(8):1093–1100. 10.1161/CIRCULATIONAHA.108.816736
13. Fung TT, Chiuve SE, McCullough ML, Rexrode KM, Logroscino G, Hu FB (2008) Adherence to a DASH-style diet and risk of coronary heart disease and stroke in women. Arch Intern Med 168(7):713–720. 10.1001/archinte.168.7.713
14. Satija A, Bhupathiraju SN, Rimm EB et al (2016) Plant-Based Dietary Patterns and Incidence of Type 2 Diabetes in US Men and Women: Results from Three Prospective Cohort Studies. PLoS Med 13(6):e1002039. 10.1371/journal.pmed.1002039
15. Schenk JM, Liu M, Neuhouser ML et al (2023) Dietary Patterns and Risk of Gleason Grade Progression among Men on Active Surveillance for Prostate Cancer: Results from the Canary Prostate Active Surveillance Study. Nutr Cancer 75(2):618–626. 10.1080/01635581.2022.2143537
16. Gregg JR, Zhang X, Chapin BF et al (2021) Adherence to the Mediterranean diet and grade group progression in localized prostate cancer: An active surveillance cohort. Cancer 127(5):720–728. 10.1002/cncr.33182
17. Siddiqui ST, Munro HM, Yu D, Zheng W, Blot WJ, Shrubsole MJ (2025) Cancer incidence and mortality risk: associations with diet quality scores in a predominantly low-income and Black cohort study. Am J Clin Nutr 122(5):1174–1184. 10.1016/j.ajcnut.2025.08.018
18. Liu VN, Van Blarigan EL, Zhang L et al (2024) Plant-Based Diets and Disease Progression in Men With Prostate Cancer. JAMA Netw Open 7(5):e249053. 10.1001/jamanetworkopen.2024.9053
19. Bowman SA, Clemens JC, Friday JE, Lynch KL, LaComb RP, Moshfegh AJ Food Patterns Equivalents Intakes by Americans: What We Eat in America, NHANES 2003–2004 and 2013–2014. FSRG Dietary Data Briefs. Beltsville (MD)2010
20. Loeb S, Fu BC, Bauer SR et al (2022) Association of plant-based diet index with prostate cancer risk. Am J Clin Nutr 115(3):662–670. 10.1093/ajcn/nqab365
21. Monda SM, Demus T, Jaime-Casas S et al (2025) Trends in Surgical Overtreatment of Prostate Cancer. JAMA Oncol 11(7):700–706. 10.1001/jamaoncol.2025.0963
22. Kim H, Caulfield LE, Garcia-Larsen V, Steffen LM, Coresh J, Rebholz CM (2019) Plant-Based Diets Are Associated With a Lower Risk of Incident Cardiovascular Disease, Cardiovascular Disease Mortality, and All-Cause Mortality in a General Population of Middle-Aged Adults. J Am Heart Assoc 8(16):e012865. 10.1161/JAHA.119.012865
23. Wang RJ, Tang JE, Chen Y, Gao JG (2015) Dietary fiber, whole grains, carbohydrate, glycemic index, and glycemic load in relation to risk of prostate cancer. Onco Targets Ther 8:2415–2426. 10.2147/OTT.S88528

24. Sidahmed E, Freedland SJ, Wang M et al (2025) Dietary Fiber Intake and Risk of Advanced and Aggressive Forms of Prostate Cancer: A Pooled Analysis of 15 Prospective Cohort Studies. J Acad Nutr Diet 125(1):11–23e22. 10.1016/j.jand.2024.04.006
25. Pettersson A, Kasperzyk JL, Kenfield SA et al (2012) Milk and dairy consumption among men with prostate cancer and risk of metastases and prostate cancer death. Cancer Epidemiol Biomarkers Prev 21(3):428–436. 10.1158/1055-9965.EPI-11-1004
26. Nouri-Majd S, Salari-Moghaddam A, Aminianfar A, Larijani B, Esmaillzadeh A (2022) Association Between Red and Processed Meat Consumption and Risk of Prostate Cancer: A Systematic Review and Meta-Analysis. Front Nutr 9:801722. 10.3389/fnut.2022.801722
27. Zhao J, Stockwell T, Roemer A, Chikritzhs T (2016) Is alcohol consumption a risk factor for prostate cancer? A systematic review and meta-analysis. BMC Cancer 16(1):845. 10.1186/s12885-016-2891-z
28. Cao S, Liu L, Yin X, Wang Y, Liu J, Lu Z (2014) Coffee consumption and risk of prostate cancer: a meta-analysis of prospective cohort studies. Carcinogenesis 35(2):256–261. 10.1093/carcin/bgt482
29. Gregg JR, Lopez DS, Reichard C et al (2019) Coffee, Caffeine Metabolism Genotype and Disease Progression in Patients with Localized Prostate Cancer Managed with Active Surveillance. J Urol 201(2):308–314. 10.1016/j.juro.2018.08.048
30. Klein EA, Thompson IM Jr., Tangen CM et al (2011) Vitamin E and the risk of prostate cancer: the Selenium and Vitamin E Cancer Prevention Trial (SELECT). JAMA 306(14):1549–1556. 10.1001/jama.2011.1437

Figures

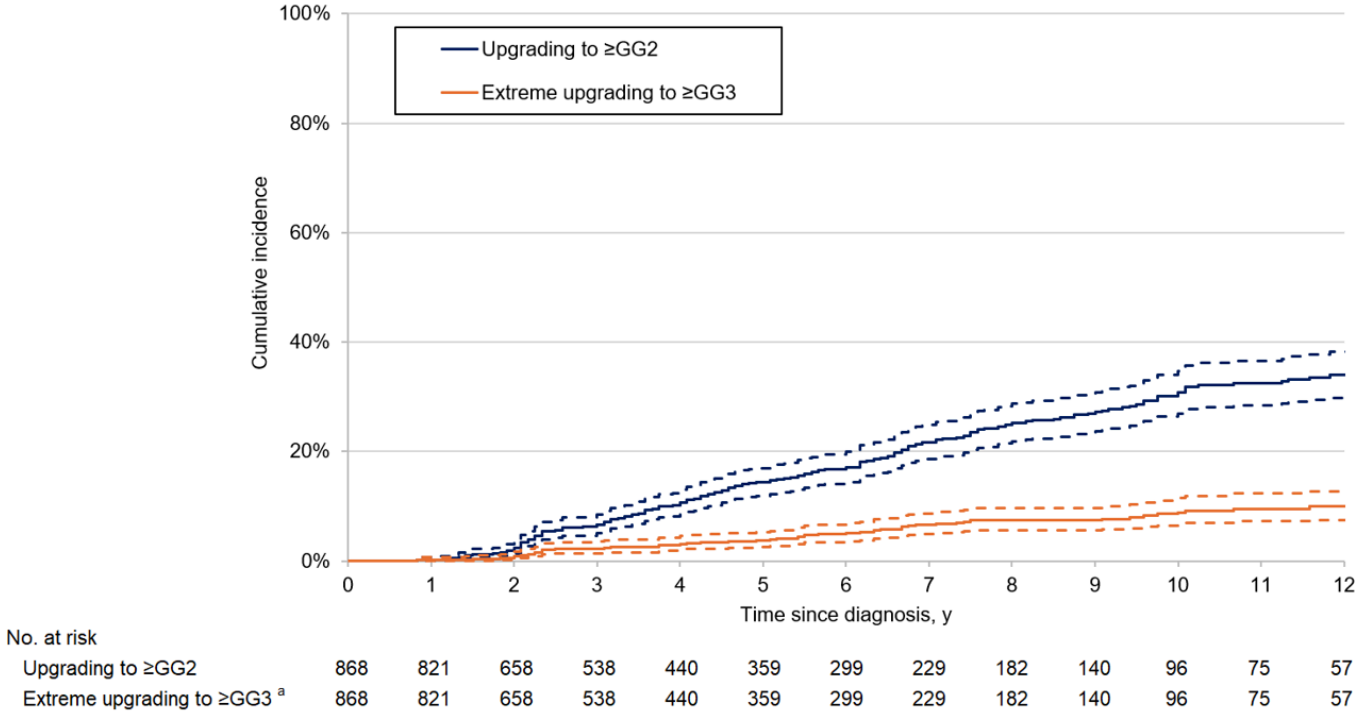

Figure 1

Cumulative incidence of prostate cancer grade progression during active surveillance.

The cumulative incidence of prostate cancer upgrading to grade group (GG) ≥2 (higher solid curve, accompanied by dashed curves for upper and lower 95% confidence interval bounds) and extreme upgrading to ≥GG3 (lower solid curve with dashed curves for confidence interval bounds) on a surveillance biopsy in 868 men diagnosed with GG1 disease managed with active surveillance. Median follow-up duration was 7.9 years (quartiles 4.5 to 11.6 years).

[a] Men with upgrading to GG2 on a surveillance biopsy would no longer be followed on active surveillance and hence would not be at risk for upgrading to ≥GG3.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- ASdietpatternsnutrientsSupplements.pdf