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Pre- and post-diagnosis dietary patterns and overall survival in patients with epithelial ovarian cancer: a prospective cohort study

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Abstract

Background Previous studies have examined the associations between individual foods or nutrients, but few studies have considered dietary patterns associated with ovarian cancer (OC) survival.

Methods In a prospective cohort study, we examined the association between pre-diagnosis and post-diagnosis overall diet, including changes from pre-diagnosis to post-diagnosis, and overall survival (OS) in 560 patients with OC. Dietary intake was collected using a valid 111-item food frequency questionnaire. Principal component analysis was performed to determine the dietary patterns. Cox proportional hazard regression models were used to assess the hazard ratio (HRs) and 95% confidence interval (CIs).

Results Two dietary patterns were identified: Balanced and nutritious pattern and Energy-dense pattern. The highest tertile of the post-diagnosis Balanced and nutritious pattern scores was related to better OS compared with the lowest tertile (HR = 0.40, 95% CI = 0.17–0.95, $P_{trend} < 0.05$). However, no significant association between pre-diagnosis and post-diagnosis Energy-dense pattern scores and OS was observed. Compared to those who had persistently high Balanced and nutritious pattern scores, patients who changed from a high score of pre-diagnosis Balanced and nutritious pattern to low post-diagnosis, as well as those who shifted from a low to a high score, both had a decreased OS ($HR_{high–low\ vs.\ high–high} = 1.91$, 95% CI = 1.18–3.08; $HR_{low–high\ vs.\ high–high} = 2.19$, 95% CI = 1.24–3.86). Additionally, patients who changed from a high pre-diagnosis score to a low post-diagnosis score had a decreased OS compared to those with consistently low Energy-dense pattern scores ($HR_{high–low\ vs.\ low–low} = 1.74$, 95% CI = 1.06–2.84).

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Conclusions Greater adherence to the Balanced and nutritious pattern as well as less adherence to the Energy-dense pattern from pre-diagnosis to post-diagnosis were associated with better OC survival.

Keywords Cohort, Dietary pattern, Ovarian cancer, Principal component analysis, Survival

Introduction

Gynecological cancer poses a significant global public health concern, with ovarian cancer (OC) as one of the most prevalent malignancies affecting women globally. Due to the insidious onset and lack of typical symptoms of OC, most patients were diagnosed in the advanced stages [1], and mortality ranks first among gynecological malignancies [2]. In 2022, 324,398 women were diagnosed with OC and 206,839 deaths occurred globally [3]. According to the Cancer Statistics, 2024, in the United States alone, 19,680 new OC cases and 12,740 OC deaths are projected to occur [4]. Despite significant advancements in diagnostic techniques and therapeutic approaches, patients with OC often confront an unfavorable prognosis, with the five-year survival rate remaining below 50% [5, 6]. While factors like age at diagnosis, histological type, and the International Federation of Gynecology and Obstetrics (FIGO) stage influence OC prognosis [7–9], most are non-modifiable. Accumulating evidence has indicated that diet serves as a viable intervention target, potentially influencing the survival rates of patients with OC [10–12].

During the past decade, a significant body of epidemiological research has concentrated on the association between specific nutrients and foods and OC survival [11, 13, 14]. However, it is recognized that analyzing single food items or nutrients alone is insufficient to capture the intricate interactions among various nutrients [11, 15]. Therefore, dietary pattern analysis serves as an alternative and complementary approach to identifying the connections between diet and disease risk. The most important methods for extracting dietary patterns are a priori or researcher-driven, and a posteriori or data-driven approaches. Within the posterior approaches, principal component analysis is the most used method [16–18]. However, evidence on whether dietary patterns are associated with survivorship among patients with OC is limited. For example, our colleagues found that pre-diagnosis healthy patterns were associated with better OC survival based on a prospective cohort study of 853 patients with OC [19]. Unlike existing scores such as HEI and AHEI, which are based on predetermined criteria and may not accurately reflect the actual diet of a specific population, Principal Component Analysis (PCA) can identify dominant dietary patterns across different populations [20]. PCA-generated dietary patterns offer greater flexibility and adaptability to diverse populations with varying cultural backgrounds. This approach can be readily applied in various research and practical settings to cater to the needs of different groups [21].

Remarkably, to our knowledge, while several studies have explored dietary patterns in relation to OC through a priori method [22–24], comprehensive assessments of the association of pre-diagnosis and post-diagnosis dietary patterns, as well as their changes from pre-diagnosis to post-diagnosis, with survival in patients with OC through posteriori method remain limited [19]. Thus, we carried out the present study of patients with OC to elucidate the aforementioned topic based on the ovarian cancer follow-up study (OOPS).

Materials and methods

OOPS study participants

The Ovarian Cancer Follow-Up Study (OOPS) was aimed to investigate the association of demographic, clinical, and lifestyle characteristics with OC prognosis [25]. The study was conducted on women aged 18–79 years newly diagnosed with OC and was approved by the Institutional Review Board of the Ethics Committee of Shengjing Hospital of China Medical University, with all women signing informed consent forms. A total of 1,082 patients diagnosed with epithelial OC were recruited between January 2015 and August 2022.

Of those, 985 patients (91%) agreed to participate and 602 patients (56%) returned questionnaires containing complete pre-diagnosis and post-diagnosis information. Moreover, 18 patients (2%) who reported implausible caloric intake (< 500 or > 3500 kcal per day) [26] and 13 patients (1%) who left 11 or more food items blank, and 11 patients (1%) who lacked crucial clinical information were excluded. A total of 560 patients with OC were included in the final analysis (Fig. 1).

Data collection

We used questionnaires to collect data from patients with OC. The pre-diagnosis data were determined by completing a questionnaire after diagnosis, and post-diagnosis data were determined at follow-up 12 months later. Our study began at the time of questionnaire completion. All participants were diagnosed at Shengjing Hospital, with no more than six months between diagnosis and completion of the questionnaire [24, 25, 27]. We collected information on pre-diagnosis and post-diagnosis demographic and lifestyle characteristics through self-administered questionnaires, including diet, cigarette smoking, alcohol and tea drinking, menopause status, parity, education, income, and physical activity. Anthropometrics,

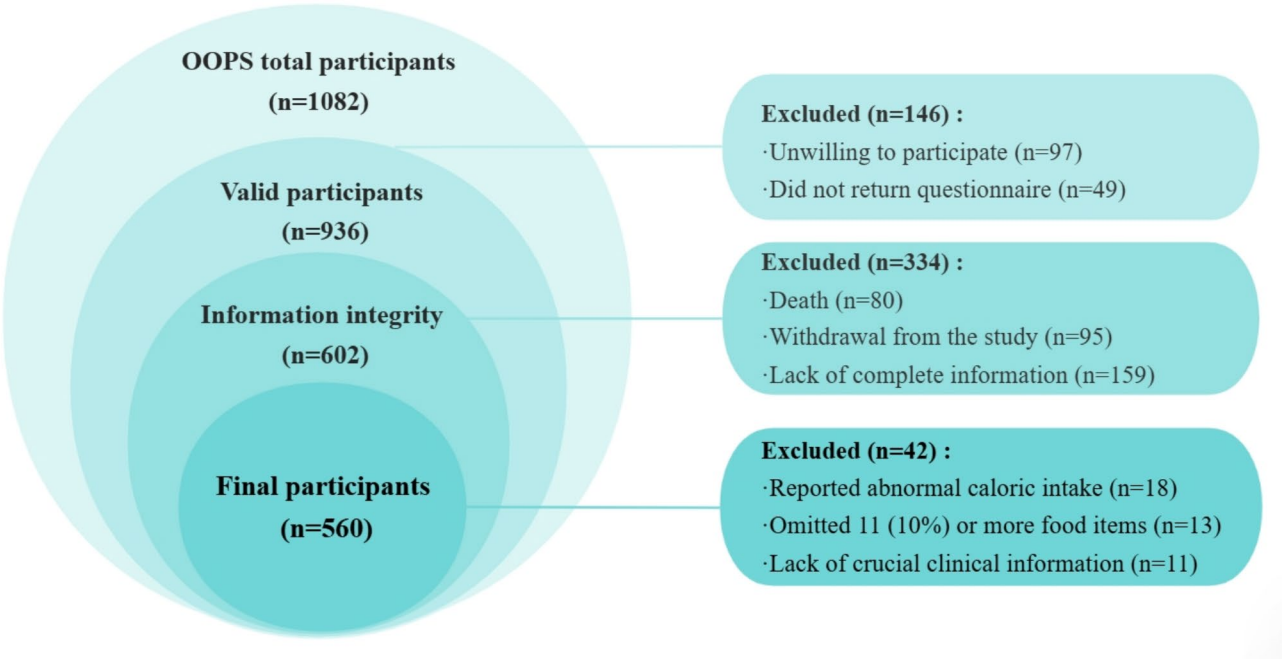

Fig. 1 The flow of participants in the Ovarian Cancer Follow-up Study (OOPS)

including weight and height [used to calculate body mass index (BMI)], were measured at baseline and follow-up. In addition, clinically relevant covariates, including age at diagnosis, histological type (serous and non-serous), FIGO stage (I-II and III-IV), residual lesions (none, < 1 cm, and ≥ 1 cm), and comorbidities (hypertension, coronary heart disease, diabetes, and other types of cancers) [28], were collected from the electronic medical records of the Shengjing Hospital information system.

Dietary assessment and dietary pattern

Participants' dietary information was assessed using a validated 111-item food frequency questionnaire (FFQ). Assessment of pre-diagnosis and post-diagnosis diets was carried out during face-to-face interviews. All patients were asked to recall the intake frequency of these food items in the year before diagnosis and after diagnosis, categorized into seven levels (almost never, 2–3 times per month, 1 time per week, 2–3 times per week, 4–6 times per week, 1 time per day, and ≥ 2 times per day). The consumption of each food item was calculated by multiplying fitted portion sizes (gram/time) by the consuming frequency of each food item consumed per day. Total energy intake and the nutrients of the food items were calculated based on the Chinese Food Composition Table [29]. The FFQ's reliability and validity were assessed previously, with reproducibility coefficients (Spearman and intraclass correlation coefficients) exceeding 0.5 and validity coefficients ranging from 0.26 to 0.70 for the main food groups, indicating reasonably valid measurements of dietary intake. Furthermore, participants were queried about any changes in their dietary habits, with response options including "never," "changed 3 years ago," "changed 2 years ago," and "changed in the present year".

We reclassified 111 foods into 19 pre-determined food groups (Supplementary Table S1) [30]. Food items with similar nutrient contents were combined (e.g., preserved eggs and boiled eggs were grouped as eggs) [30]. Foods that did not fit in a category or did not load on any factor were not used for further analysis, such as sesame and its products, ice-cream, fermented bean curd, and soy sauce [20]. For each participant, the average daily intake of each food group was calculated by summing the intake of the individual foods in that food group.

We performed two factor analyses (principal component analyses) for 19 food groups before and after diagnosis to derive food group-based dietary patterns [21]. The retained factors were rotated (varimax rotation) to obtain an orthogonal solution [31]. We selected the number of factors to retain by considering the point at which the scree plot leveled off, eigenvalue > 1.0, and interpretability [32]. Furthermore, food items with absolute factor loadings that were ≥|0.3| accounted for each component [33–35]. Food groups were not included if they had an absolute loading of <|0.3|. Finally, two major dietary patterns were identified (Table 1), which we called the Balanced and nutritious pattern and the Energy-dense pattern.

Follow-up and outcome

The vital status of the participants was obtained through the medical records of Shengjing Hospital and active

Table 1 Factor loadings scores of food groups of dietary patterns

Food groups	Balanced and nutritious pattern		Energy-dense pattern	
	Pre-diagnosis	Post-diagnosis	Pre-diagnosis	Post-diagnosis
Refined grain	0.54	0.32	-	-
Whole grain	0.59	0.52	-	-
Baked goods	-	-	0.36	0.48
Fried food	-	-	-	0.65
Milk and dairy products	0.50	0.44	-	-
Fish and seafood	0.36	0.45	0.49	-
Meat	0.44	0.40	-	0.33
Animal liver and blood products	-	-	0.42	0.39
Eggs	0.54	0.62	-	-
Rhizome species	0.56	0.60	-	-
Vegetables	0.73	0.80	-	-
Fruits	0.60	0.61	-	-
Beans and soy products	0.33	0.58	0.61	-
Preserved food	-	-	0.67	0.43
Nuts	0.47	0.44	-	-
Tea	-	-	-	0.54
Coffee	-	-	0.41	0.38
Juice & Beverage	-	-	0.59	0.41
Alcoholic drinks	-	-	0.70	0.47
Explained variation in food groups, %	19.28	11.35	19.94	8.99

Factor loadings represent the relative contribution of each food group to the dietary pattern. Only food groups that satisfy factor loadings ≥|0.3| are displayed and listed for simplicity and ease of interpretatio

follow-up. The study was followed up every six months. Survival time was defined as the interval between the histological diagnosis of OC and the date of death from any cause or the date of last follow-up (February 16, 2023) for patients who were still alive. The main outcome of this study was all-cause mortality.

Statistical analyses

All continuous variables were shown as the mean with standard deviation (SD) or median with interquartile (IQR) according to data distribution characteristics, and categorical variables were shown as counts as well as percentages. The distribution of participants in terms of demographic and clinical characteristics across dietary patterns was examined using the one-way analyses of variance (ANOVA) for continuous variables and the Chi-square test for categorical variables. In addition, we used the Wilcoxon test and Chi-square test to compare the characteristics of patients with and without information loss to determine whether our findings are representative of the overall population. The Kaplane-Meier technique was applied to estimate crude overall survival (OS) probabilities and plot crude survival curves (Fig. 2). To ensure consistency in pre-diagnosis and post-diagnosis dietary patterns, factor score coefficients after diagnosis were cross-checked with results at baseline using Pearson product difference correlation (r) [36]. The factor score for each pattern was found by summing intakes of food groups weighted by factor loading, and each individual received a factor score for each identified pattern.

For further analyses, we divided the factor scores into three groups, with the lowest tertile as the reference group. We used Cox proportional hazards regression models to evaluate the hazard ratios (HRs) and 95% confidence intervals (CIs) for the associations of pre-diagnosis and post-diagnosis dietary patterns with OC survival after adjusting for potential confounders. Directed acyclic graphs were used to identify potential confounders (Supplementary Figure S1) [37]. Before the Cox regression analyses, we evaluated the proportional hazards assumption by adding an interaction term between each activity variable and log survival time. If the proportional risk hypothesis is not satisfied ($P < 0.05$), the time-dependent Cox regression model is used. Tests for linear trends were assessed by including a continuous variable for the median score within each tertile in the respective regression model.

We conducted three sets of analyses. Firstly, we analyzed the association between pre-diagnosis and post-diagnosis dietary patterns and OS. In both analyses, we selected age at diagnosis (< 50 or ≥ 50 years), total energy intake (continuous, kcal/d), changes in dietary habits (yes or no), BMI (continuous, kg/m^2), comorbidities (yes or no), education (junior secondary or below, senior high school/technical secondary school, and junior college/university or above), FIGO stage (I-II or III-IV), histological type (serous or non-serous), menopausal status (yes

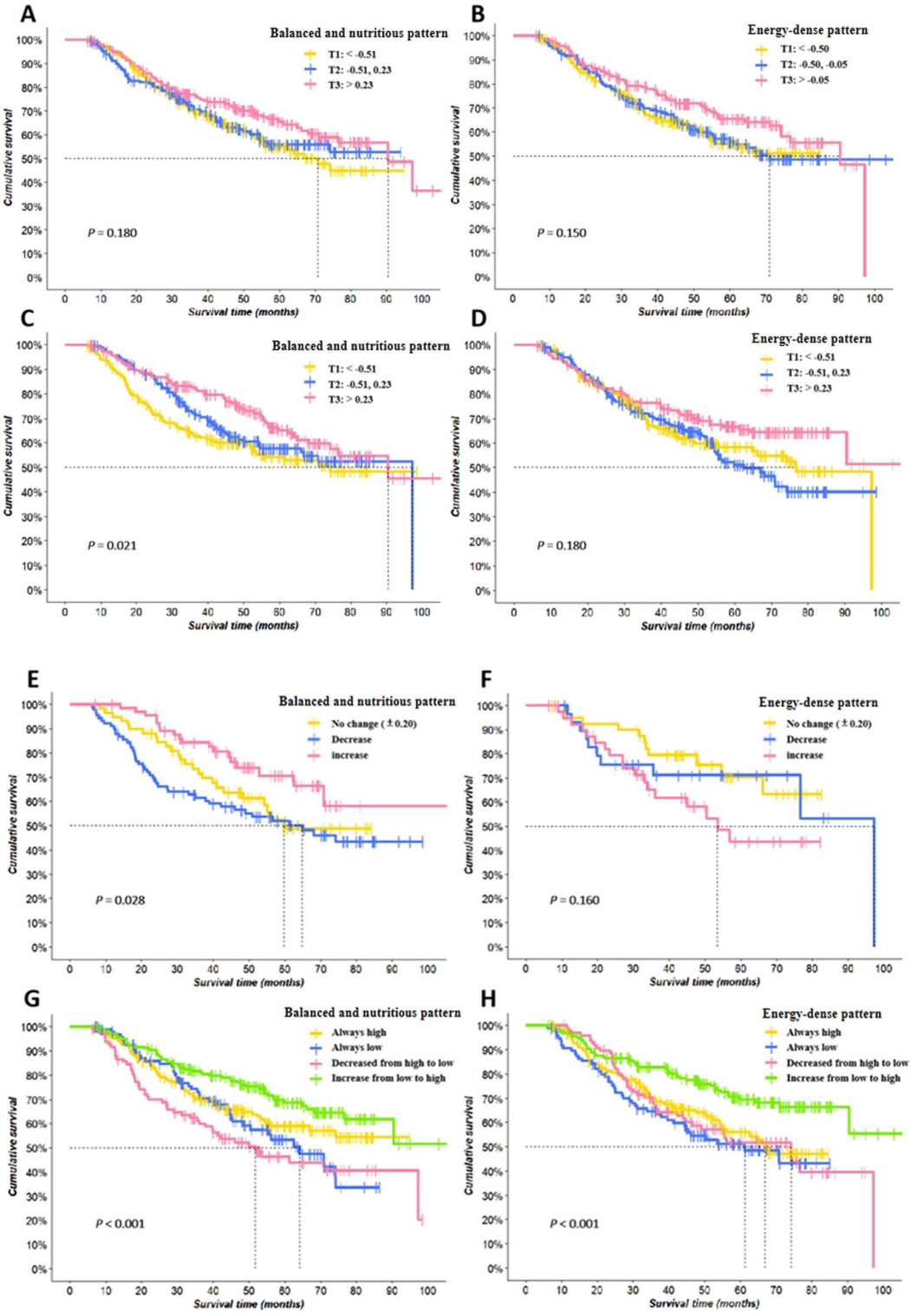

Fig. 2 Kaplan-Meier survival curves for pre-diagnosis Balanced and nutritious pattern (**A**), pre-diagnosis Energy-dense pattern (**B**), post-diagnosis Balanced and nutritious pattern (**C**), post-diagnosis Energy-dense pattern (**D**), change in scores of pre-diagnosis and post-diagnosis Balanced and nutritious pattern (**E**), change in scores of pre-diagnosis and post-diagnosis Energy-dense pattern (**F**), change in pre-diagnosis and post-diagnosis scores of Balanced and nutritious pattern by categories of the scores change groups (**G**), and change in pre-diagnosis and post-diagnosis scores of Energy-dense pattern by categories of the scores change groups (**H**)

or no), parity (≤1 or ≥2), residual lesions (none, < 1 cm, or ≥1 cm), physical activity (continuous, MET/h/d), cigarette smoking (yes or no), and another dietary pattern as covariates.

Secondly, to investigate how these two dietary patterns changed before and after OC diagnosis, we further examined the cross-classification (i.e., joint effect) of categories of Balanced and nutritious pattern and Energy-dense pattern [38]. We used a baseline median score to rate each dietary pattern's factor scores as low or high. Low means the score is less than or equal to the median, and high means the score is greater than the median [22]. Patients were divided into four groups based on whether the score change for each dietary pattern was always low, always high, increased from low to high, or decreased from high to low [22]. In this analysis, we adjusted for the same covariates other than changes in dietary habits and adjusted for changes in pre-diagnosis and post-diagnosis physical activity (quintile), total energy intake (quintile), BMI (quintile), and smoking status (categorical) [39].

To verify the reliability of the main results, several subgroup analyses were conducted, stratified by age of diagnosis (<50 and ≥50 years), BMI (<24 and ≥24 kg/m^2), histological type (serous and non-serous), FIGO stage (I-II and III-IV), comorbidities (no and yes), and residual lesions (no and yes). Based on the multivariate Cox model, the cross-product of exposed variables and stratified variables is added to assess the multiplicative interactions. Additive interactions were estimated by calculating the relative excess risk due to interaction.

Additionally, two sensitivity analyses were performed. First, patients in FIGO stage IV were excluded. Second, the E-value, an alternative method for sensitivity analysis of unmeasured confounders in observational studies, was calculated [40]. The E-value quantifies the minimum strength of association on the risk ratio scale that an unmeasured confounder must have to negate the observed results [41]. A higher E-value indicates that stronger unmeasured confounding is required to explain the observed association [41]. All statistical analyses were conducted by SAS version 9.4 (SAS Institute, Cary, NC, USA). All reported *P* values were two-tailed with the level of significance set at 0.05.

Results

The principal component analysis identified two major dietary patterns, termed Balanced and nutritious pattern and Energy-dense pattern, explaining 39.22% and 20.34% of the variation in food intake before and after diagnosis, respectively (Table 1). Significant positive correlations were observed between pre-diagnosis and post-diagnosis dietary patterns. (Balanced and nutritious pattern: $r=0.854$, $P<0.01$; Energy-dense pattern: $r=0.730$, $P<0.01$). Supplementary Table S1 illustrates all pre-diagnosis and post-diagnosis food groups.

Baseline characteristics according to dietary pattern of patients with OC were summarized in Table 2. In the Balanced and nutritious pattern, patients with high scores had more physical activities, higher education levels, longer survival time, and were mostly free of comorbidities. In the Energy-dense pattern, patients with high scores were more likely to have no or smaller residual lesions, serous histological types, and fewer number of parity. In addition, we compared the characteristics of patients with and without information loss, and the *P*-values of all variables in the baseline were both >0.05.

Table 3 revealed the relationship between pre-diagnosis and post-diagnosis dietary patterns and OS among patients with OC. No significant association was observed between the pre-diagnosis Balanced and nutritious pattern or the Energy-dense pattern adherence and OS. As for the scores of post-diagnosis dietary patterns, the highest tertile of the scores of Balanced and nutritious pattern (HR = 0.40, 95% CI = 0.17–0.95, P_{trend} = 0.01) was related to better OS compared with the lowest tertile. However, no significant associations were found between the post-diagnosis Energy-dense pattern and the OS.

Next, we examined the association between changes in dietary pattern scores from pre-diagnosis to post-diagnosis and OS (Supplementary Table S2). Compared to persistently high Balanced and nutritious pattern scores, patients who changed from a high score of pre-diagnosis Balanced and nutritious pattern to a low post-diagnosis score, as well as those who shifted from a low to high score, both had a decreased OS ($HR_{high–low\ vs.\ high–high}$ = 1.91, 95% CI = 1.18–3.08; $HR_{low–high\ vs.\ high–high}$ = 2.19, 95% CI = 1.24–3.86). Additionally, patients who changed from a high pre-diagnosis score to a low post-diagnosis score had a decreased OS compared to those with consistently low Energy-dense pattern scores ($HR_{high–low\ vs.\ low–low}$ = 1.74, 95% CI = 1.06–2.84).

In subgroup analyses stratified by demographic and clinical characteristics, most findings were consistent with the main results, though not all achieved statistical significance (Fig. 3).

In the sensitivity analyses, we excluded individuals with the FIGO stage IV for analysis. The result was consistent with the main findings (data not shown). Additionally, we calculated E-values to quantify the possible association of unmeasured confounders. Within the meaningful scores we examined, the largest E-value stood at 4.45 and the smallest was 1.09. This means that if there is an unmeasured covariate with a HR association of at least 2.72 for OC versus dietary patterns, then residual confounding can explain the observed association.

Table 2 General characteristics of 560 patients with ovarian cancer according to pre-diagnosis dietary pattern

Variables	Balanced and nutritious pattern			Energy-dense pattern		
	Tertile 1	Tertile 2	Tertile 3	Tertile 1	Tertile 2	Tertile 3
No. of patients	186	186	188	186	186	188
Age at diagnosis (years)	53.00 (47.00, 58.00)	52.50 (48.00, 59.00)	54.00 (48.00, 61.00)	54.00 (48.00, 60.00)	52.00 (47.00, 59.00)	53.00 (46.00, 60.00)
Survival time (months)	43.90 (25.33, 59.20)	42.12 (24.53, 57.50)	48.47 (29.72, 68.07)	41.50 (24.53, 55.67)	45.80 (28.07, 60.13)	47.35 (28.60, 74.64)
Body mass index (kg/m^2)	23.34 (20.83, 24.98)	22.96 (20.66, 24.47)	22.88 (21.20, 24.81)	22.88 (20.31, 24.61)	22.93 (21.09, 24.39)	23.54 (21.42, 25.39)
Physical activity (MET*h/d)	11.70 (6.10, 17.88)	9.93 (5.41, 17.46)	10.07 (5.60, 18.77)	11.00 (6.10, 17.30)	10.98 (5.60, 19.56)	10.36 (5.60, 18.67)
Total energy intake (kcal/d)	973.71 (837.72, 1182.14)	1324.67 (1120.42, 1649.00)	1813.69 (1517.67, 2212.55)	1105.67 (958.08, 1339.61)	1315.60 (1047.87, 1668.60)	1787.6 (1382.37, 2239.23)
Diet change						
No	139 (74.73)	147 (79.03)	127 (67.55)	134 (72.04)	140 (75.27)	139 (73.94)
Yes	47 (25.27)	39 (20.97)	61 (32.45)	52 (27.96)	46 (24.73)	49 (26.06)
Smoking status						
No	158 (84.95)	171 (91.94)	172 (91.49)	174 (93.55)	165 (88.71)	162 (86.17)
Yes	28 (15.05)	15 (8.06)	16 (8.51)	12 (6.45)	21 (11.29)	26 (13.83)
Menopausal status						
No	63 (33.87)	65 (34.95)	42 (22.34)	49 (26.34)	59 (31.72)	62 (32.98)
Yes	123 (66.13)	121 (65.05)	146 (77.66)	137 (73.66)	127 (68.28)	126 (67.02)
Parity						
≤ 1	139 (74.73)	137 (73.66)	127 (67.55)	125 (67.20)	131 (70.43)	147 (78.19)
> 1	47 (25.27)	49 (26.34)	61 (32.45)	61 (32.80)	55 (29.57)	41 (21.81)
Educational level						
Junior secondary or below	110 (59.14)	103 (55.38)	115 (61.17)	125 (67.21)	105 (56.45)	98 (52.13)
Senior high school/technical secondary school	37 (19.89)	44 (23.65)	29 (15.43)	29 (15.59)	44 (23.66)	37 (19.68)
Junior college/university or above	39 (20.97)	39 (20.97)	44 (23.40)	32 (17.20)	37 (19.89)	53 (28.19)
Income per month (Yuan)						
< 5000	118 (63.44)	103 (55.38)	91 (48.40)	111 (59.68)	101 (54.30)	100 (53.19)
5000 to < 10,000	46 (24.73)	50 (26.88)	67 (35.64)	53 (28.49)	54 (29.03)	56 (29.79)
≥ 10,000	22 (11.83)	33 (17.74)	30 (15.96)	22 (11.83)	31 (16.67)	32 (17.02)
Age at diagnosis						
≤ 50	70 (37.63)	70 (37.63)	69 (36.70)	62 (33.33)	72 (38.71)	75 (39.89)
> 50	116 (62.37)	116 (62.37)	119 (63.30)	124 (66.67)	114 (61.29)	113 (60.11)
FIGO stage						
I-II	86 (46.24)	61 (32.80)	82 (43.62)	71 (38.17)	77 (41.40)	81 (43.09)
III-IV	100 (53.76)	125 (67.20)	106 (56.38)	115 (61.83)	109 (58.60)	107 (56.91)
Residual lesions						
No	154 (82.80)	144 (77.42)	147 (78.19)	144 (77.42)	146 (78.49)	155 (82.45)
≤ 1 cm	25 (13.44)	26 (13.98)	30 (15.96)	28 (15.05)	29 (15.59)	24 (12.76)
> 1 cm	7 (3.76)	16 (8.60)	11 (5.85)	14 (7.53)	11 (5.91)	9 (4.79)
Comorbidities						
No	102 (54.84)	115 (61.83)	708 (57.45)	108 (58.06)	112 (60.22)	105 (55.85)
Yes	84 (45.16)	71 (38.17)	80 (42.55)	78 (41.94)	74 (39.78)	83 (44.15)
Histological type						
Serous	132 (70.97)	146 (78.49)	141 (75.00)	140 (75.27)	135 (72.58)	144 (76.60)
Non-serous	54 (29.03)	40 (21.51)	47 (25.00)	46 (24.73)	51 (27.42)	44 (23.40)

FIGO, The International Federation of Gynecology and Obstetrics; MET, metabolic equivalent task

Values are numbers (percentages) for categorical variables and median (interquartile range) for continuous variables

Table 3 Associations between pre-diagnosis and post-diagnosis dietary patterns and ovarian cancer survival

Dietary patterns	Tertiles of dietary pattern scores			*P* for trend [g]	HR for continuous
	Tertile 1	Tertile 2	Tertile 3		
Pre-diagnosis					
Balanced and nutritious pattern	< -0.51	-0.51, 0.23	> 0.23		
Deaths/Total	77/186	69/186	65/188		
HR (95% CI) in Model 1 [a]	1.00 (ref.)	0.97 (0.69, 1.38)	0.85 (0.54, 1.32)	0.46	0.90 (0.73, 1.10)
HR (95% CI) in Model 2 [b]	1.00 (ref.)	0.92 (0.65, 1.30)	0.81 (0.52, 1.26)	0.35	0.89 (0.72, 1.10)
HR (95% CI) in Model 3 [c]	1.00 (ref.)	0.80 (0.55, 1.16)	0.73 (0.44, 1.19)	0.22	0.81 (0.62, 1.04)
Energy-dense pattern	< -0.50	-0.50, -0.05	> -0.05		
Deaths/Total	72/186	77/186	62/188		
HR (95% CI) in Model 1 [a]	1.00 (ref.)	1.02 (0.74, 1.42)	0.85 (0.58, 1.24)	0.34	0.97 (0.82, 1.15)
HR (95% CI) in Model 2 [b]	1.00 (ref.)	1.07 (0.77, 1.49)	0.94 (0.64, 1.40)	0.70	1.01 (0.85, 1.21)
HR (95% CI) in Model 3 [c]	1.00 (ref.)	1.13 (0.81, 1.58)	0.92 (0.60, 1.41)	0.60	0.92 (0.75, 1.14)
Post-diagnosis					
Balanced and nutritious pattern	< -0.51	-0.51, 0.31	> 0.31		
Deaths/Total	79/186	73/186	59/188		
HR (95% CI) in Model 1 [d]	1.00 (ref.)	0.55 (0.36, 0.84)	0.31 (0.14, 0.69)	< 0.01	0.59 (0.44, 0.79)
HR (95% CI) in Model 2 [e]	1.00 (ref.)	0.57 (0.37, 0.89)	0.35 (0.15, 0.79)	0.01	0.62 (0.46, 0.83)
HR (95% CI) in Model 3 [f]	1.00 (ref.)	0.57 (0.36, 0.90)	0.40 (0.17, 0.95)	0.01	0.59 (0.41, 0.85)
Energy-dense pattern	< -0.46	-0.46, 0.06	> 0.06		
Deaths/Total	71/186	80/186	60/188		
HR (95% CI) in Model 1 [d]	1.00 (ref.)	0.99 (0.72, 1.37)	1.00 (0.69, 1.43)	0.98	1.09 (0.92, 1.29)
HR (95% CI) in Model 2 [e]	1.00 (ref.)	1.03 (0.75, 1.43)	1.04 (0.72, 1.50)	0.86	1.10 (0.93, 1.30)
HR (95% CI) in Model 3 [f]	1.00 (ref.)	1.01 (0.72, 1.41)	1.01 (0.66, 1.53)	0.97	1.00 (0.80, 1.24)

CI, confidence interval; HR, hazard ratio; Ref, reference

[a] Adjusted for age at diagnosis, total energy intake (pre-diagnosis), and body mass index (pre-diagnosis)

[b] Based on model 1 and further adjusted for changes in dietary habits (pre-diagnosis), education, menopausal status, parity, physical activity (pre-diagnosis), and smoking status (pre-diagnosis)

[c] Based on model 2 and further adjusted for FIGO stage, residual lesions, comorbidities, histological type, and another dietary pattern

[d] Adjusted for age at diagnosis, total energy intake (post-diagnosis), and body mass index (post-diagnosis)

[e] Based on model 1 and further adjusted for changes in dietary habits (post-diagnosis), education, menopausal status, parity, physical activity (post-diagnosis), and smoking status (post-diagnosis)

[f] Based on model 2 and further adjusted for FIGO stage, residual lesions, comorbidities, histological type, and another dietary pattern

[g] *P*-value for linear trend calculated from category median values

Discussion

We identified two distinct dietary patterns in this prospective cohort study. Our results demonstrated that high scores of post-diagnosis Balanced and nutritious pattern were associated with an improved OS in patients with OC, while high scores of pre-diagnosis Balanced and nutritious pattern and post-diagnosis Energy-dense pattern were not significantly associated with OS. Compared to people who consistently consumed a high pre-diagnosis and post-diagnosis balanced and nutritious diet, pre-diagnosis consuming a high diet and post-diagnosis consuming a low diet and pre-diagnosis consuming a low diet and post-diagnosis consuming a high diet was associated with worse OS. Compared to people who consistently consumed a low pre-diagnosis and post-diagnosis Energy-dense pattern, pre-diagnosis consuming a high diet and post-diagnosis consuming a low diet was associated with worse OS.

Dietary patterns are assessed using "a priori" or "a posteriori" methods [42]. The "a priori" approach involves calculating a diet index/score grounded in established associations between dietary intake and disease outcomes [43]. In examining the link between a priori dietary methods and OC, Cao et al. performed a prospective cohort study involving 636 patients with OC in 2024 [44]. Utilizing the Healthy Eating Index-2015, the Alternative Mediterranean Diet Score, and the Dietary Approaches to Stop Hypertension (DASH) score to evaluate diet quality, they found that higher adherence to quality diets pre-diagnosis was associated with improved survival rates in patients with OC. These results align with our post-diagnosis findings. Furthermore, several epidemiological investigations have also demonstrated that superior diet quality correlates with enhanced OS [11, 12, 22, 45]. Conversely, when exploring the association of a posteriori methods with OC, epidemiological evidence regarding the impact of dietary patterns on OC survival remains limited [18, 38]. A prospective cohort study of 703 patients with OC based on OOPS observed that adherence to a pre-diagnosis healthy pattern was

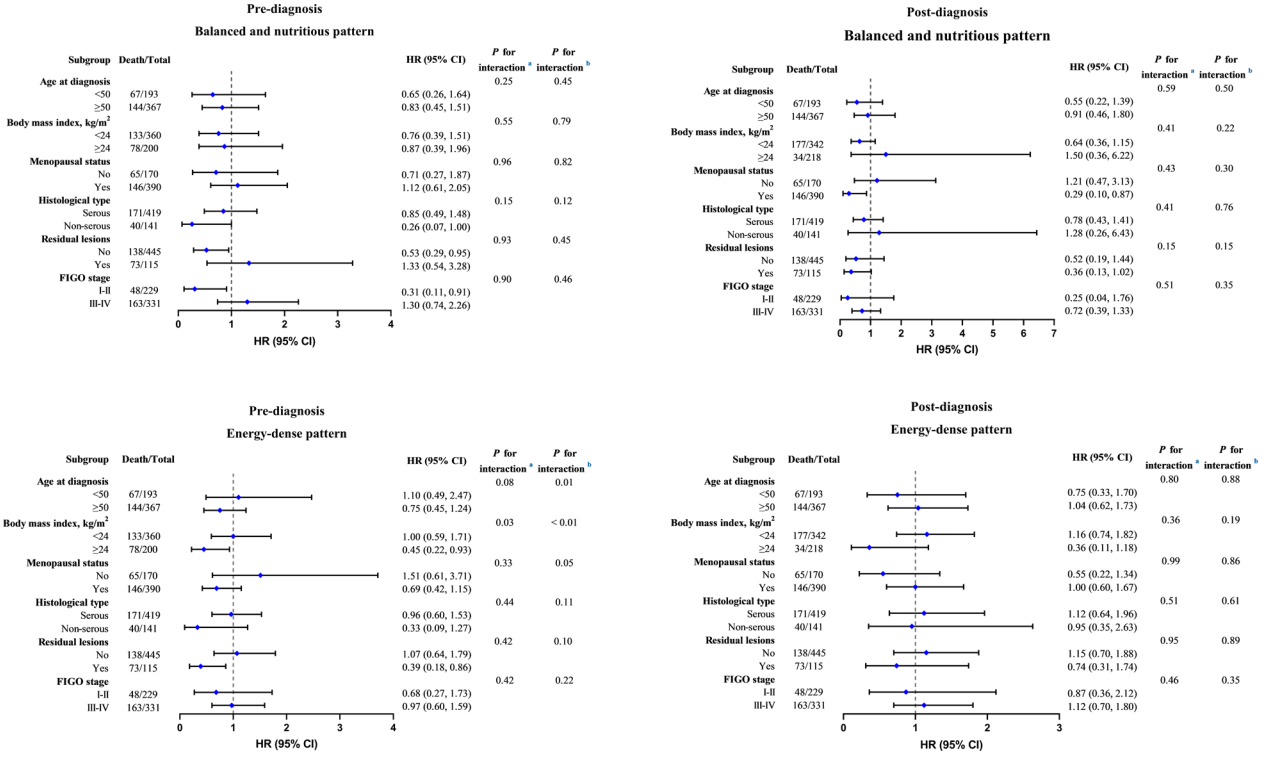

Fig. 3 Multivariable hazard ratios (HRs) and 95% CIs for overall survival among patients with ovarian cancer according to pre-diagnosis and post-diagnosis dietary patterns across strata of various factors. CI, confidence interval; FIGO, The International Federation of Gynecology and Obstetrics; HR, hazard ratio. HR (95%CI) shows the results for the highest tertile compared to the lowest tertile. The Cox model was adjusted for age at diagnosis, total energy intake (pre-diagnosis and post-diagnosis), body mass index (pre-diagnosis and post-diagnosis), changes in dietary habits (pre-diagnosis and post-diagnosis), education, menopausal status, parity, physical activity (pre-diagnosis and post-diagnosis), smoking status (pre-diagnosis and post-diagnosis), FIGO stage, residual lesions, comorbidities, histological type, and another dietary pattern. [a] Indicated *P*-value for multiplicative interaction. [b] Indicated *P*-value for additive interaction

beneficial for OC survival [19]. Their healthy pattern was similar to our Balanced and nutritious pattern. However, no association between pre-diagnosis Balanced and nutritious pattern and OC survival was found in our study, which may partly due to the limited sample size. On the other hand, as far as we know, no study has examined the association of Energy-dense pattern with survival in patients with OC. In contrast, recently, only one prospective cohort study of 97,292 female teachers in the United States investigated the relationship between fat patterns and OC risk [46]. They identified five dietary patterns based on principal component analysis, including a high-fat pattern similar to our Energy-dense pattern. However, they did not find a significant association between high-fat patterns and the risk of OC. In addition, we examined changes in dietary patterns before and after diagnosis. In a study by Naoko Sasamoto et al., it was found that a high post-diagnosis empirical dietary inflammatory pattern (EDIP) was associated with an increased risk of OC-specific mortality compared with survivors who consumed a diet with a low EDIP score before diagnosis [30]. These findings were similar to our results. However, there has been less research on changes in dietary patterns for OC and further studies are warranted to validate our findings.

Some potential biological mechanisms may explain the relationship between dietary patterns and OC survival. Firstly, diets encompass the combined intake of numerous foods and nutrients that may interact, enabling dietary patterns to detect the cumulative effect of multiple foods or nutrients within a dietary pattern, rather than focusing on a single food or nutrient [47]. Secondly, the Balanced and nutritious pattern is featured by a high intake of all types of fruits and vegetables, meat, and grains. These foods, which are higher in vitamins, antioxidants, phytochemicals, and fiber, were significantly associated with decreased risk of OC [48–50]. These nutrients possess both complementary and overlapping mechanisms of action, comprising the inhibition of nitrosamine formation, alteration of hormone metabolism, and antioxidant effects [51]. The Energy-dense pattern is characterized by a high intake of high-calorie foods, including those rich in sugars, fats, and fried items. Based on data of this cohort, we previously showed that a high frequency of fried fish intake (HR = 1.49, 95% CI = 1.03–2.16) was associated with worse OC survival

than consuming none [27]. The process of frying induces chemical alterations in food components and fats, such as polymerization, hydrogenation, and oxidation, subsequently leading to the generation of potential carcinogens like acrylamide and heterocyclic amines [46]. Preserved meats, fish, and other foodstuffs may contain nitrosamine precursor compounds, including carnitine and nitrite, which could impact cancer cells through the formation of DNA adducts [46, 52, 53].

There are several strengths in our study. Firstly, it is a well-designed prospective cohort study with a high baseline survey participation rate and a low proportion of loss to follow-up, minimizing potential bias. Secondly, unlike most previous studies that examined only pre-diagnosis diet, our study collected patients' information at baseline and post-diagnosis diet information, as well as detailed covariates, allowing us to examine changes in pre-diagnosis and post-diagnosis dietary patterns with survival [54, 55]. Besides, our study adjusted for a wide array of demographic and clinical characteristics in the multivariable analyses, which further strengthened our findings.

Nevertheless, several limitations should be noted. Firstly, dietary information was collected through FFQ, which can lead to exposure misclassification of reported and recall bias. However, there is a good correlation between FFQ and diet records, and it is highly cost-effective, so it is widely used in large-scale epidemiological cohort studies [56]. Moreover, our information on dietary intake was based on face-to-face interviews, which assured the accuracy of our study. Secondly, the current study is a hospital-based and single-center study, which may introduce selection bias. Its diverse patient population helps provide a certain degree of generalizability to the findings, though caution is still needed when extrapolating the results to other settings or populations. Thirdly, the principal component analysis is somewhat subjective to a certain extent, such as how many foods and/or food groups have been included, how many components have been retained, and/or the nomenclature of the patterns, which is also a potential limitation [32]. However, this analytical method takes advantage of the collinearity of food and nutrient combination consumption [46]. Despite our inability to capture all dietary patterns in the cohort, grouping foods into patterns is closer to dietary habits than considering foods individually. Moreover, we only focus on OS instead of progressive-free survival. However, progression-free survival was not significantly different from OS due to the poor prognosis of OC [57]. Fourthly, although we have adjusted for some important confounders in the analyses, the findings still might be affected by some unmeasured and residual confounders. However, we performed E-value calculations to quantify the potential impact of unmeasured confounders, which suggests that these unmeasured confounders may not significantly affect our conclusions. Lastly, although all patients underwent standard chemotherapy according to the guidelines [58], the information on specific treatment (such as immunotherapy or targeted therapy) was unavailable and was not included as a covariate in our analyses, which might influence our results. Still, further large sample and multi-center studies are needed in the future to verify our findings.

Conclusions

Our findings suggested that adherence to post-diagnosis Balanced and nutritious dietary pattern may be associated with better OS in patients with OC, while adherence to the Energy-dense pattern after cancer diagnosis may not be conducive to survival. In addition, compared to people who consistently consumed a high pre-diagnosis and post-diagnosis balanced and nutritious diet, scores ranging from pre-diagnosis above the median to post-diagnosis below the median, and scores ranging from pre-diagnosis below the median to post-diagnosis above the median were associated with worse OS. Compared to people who consistently consumed a low pre-diagnosis and post-diagnosis Energy-dense pattern, scores ranging from pre-diagnosis above the median to post-diagnosis below the median were associated with worse OS. These findings provide valuable insights into potential dietary recommendations for patients with OC and emphasize the necessity for further research to investigate these associations within larger and more diverse populations.

Abbreviations

BMI	Body mass index
CIs	Confidence intervals
FFQ	Food frequency questionnaire
FIGO	International Federation of Gynecology and Obstetrics
HRs	Hazard ratios
IQR	Interquartile range
OC	Ovarian cancer
OOPS	Ovarian cancer follow-up study
OS	Overall survival
SD	Standard deviation

Supplementary Information

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Supplementary Material 1

Supplementary Material 2

Supplementary Material 3

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Author contributions
YQ, X-YC, Q-PM, LW, T-TG, and Q-JW contributed to the study design. SG, Q-PM, LW, and T-TG collection of data. YQ, X-YC, FC, J-CL, and F-HL analysis of data. YQ, X-YC, FC, J-CL, LW, Y-ZL, H-LX, Y-FW, D-HH, X-YL, QX, Q-PM, LW, T-TG, and Q-JW wrote the first draft of the manuscript and edited the manuscript. All authors read and approved the final manuscript. YQ, X-YC, FC, and J-CL contributed equally to this work.

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Data availability
No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate
The OOPS was approved by the Institutional Review Board of the Ethics Committee of Shengjing Hospital of China Medical University. All of the participants signed the informed consent. All experiments were performed in accordance with relevant guidelines and regulations.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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