The synergistic impact of anti-inflammatory and nutrient-rich dietary patterns on long term prognosis among individuals with osteoarthritis

Keywords
dietary patterns, NHANES, Dietary Inflammatory Index, mortality, Osteoarthritis, Healthy Eating Index

Abstract

Introduction

To investigate the associations between healthy and anti-inflammatory dietary patterns and mortality risk in osteoarthritis (OA) patients, and to identify key dietary factors influencing long-term outcomes.

Material and methods

We analyzed data from 3,012 OA patients participating in the National Health and Nutrition Examination Survey (NHANES) between 2007 and 2018. Dietary patterns were assessed using two validated indices: the Healthy Eating Index-2015 (HEI-2015) for overall diet quality and the Dietary Inflammatory Index (DII) for inflammatory potential, both derived from 24-hour dietary recall data. Mortality outcomes were ascertained through linkage with the National Death Index. Weighted Cox proportional hazards regression models were employed to evaluate associations between dietary patterns and all-cause mortality, with adjustments for demographic, lifestyle, and clinical confounders. To identify key dietary predictors, we applied Least Absolute Shrinkage and Selection Operator (LASSO) regression. A prognostic nomogram was developed to assess predictive performance.

Results

A healthy, anti-inflammatory diet (high HEI-2015, low DII) was associated with a 14% lower mortality risk (HR: 0.86, 95% CI: 0.75–1.00, p-trend = 0.045) compared to an unhealthy, pro-inflammatory diet. LASSO regression highlighted 21 key dietary factors, including vitamins (B2, B6, B12, D, E), minerals (zinc, selenium, iron), fatty acids (n-3, n-6, monounsaturated), and whole foods (fruits, vegetables, grains). The nomogram showed reliable predictive accuracy (AUC: 0.65 at 3 years, 0.70 at 12 years). Subgroup analyses indicated stronger effects in non-smokers (HR: 0.79, 95% CI: 0.65–0.97).

Conclusions

Adopting a healthy, anti-inflammatory dietary pattern can reduce mortality rates in individuals with arthritis, with specific micronutrients and food groups playing a critical role.

The synergistic impact of anti-inflammatory and nutrient-rich dietary patterns on long term prognosis among individuals with osteoarthritis

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Abstract

Objective: To investigate the associations between healthy and anti-inflammatory dietary patterns and mortality risk in osteoarthritis (OA) patients, and to identify key dietary factors influencing long-term outcomes.

Methods: We analyzed data from 3,012 OA patients participating in the National Health and Nutrition Examination Survey (NHANES) between 2007 and 2018. Dietary patterns were assessed using two validated indices: the Healthy Eating Index-2015 (HEI-2015) for overall diet quality and the Dietary Inflammatory Index (DII) for inflammatory potential, both derived from 24-hour dietary recall data. Mortality outcomes were ascertained through linkage with the National Death Index. Weighted Cox proportional hazards regression models were employed to evaluate associations between dietary patterns and all-cause mortality, with adjustments for demographic, lifestyle, and clinical confounders. To identify key dietary predictors, we applied Least Absolute Shrinkage and Selection Operator (LASSO) regression. A prognostic nomogram was developed to assess predictive performance.

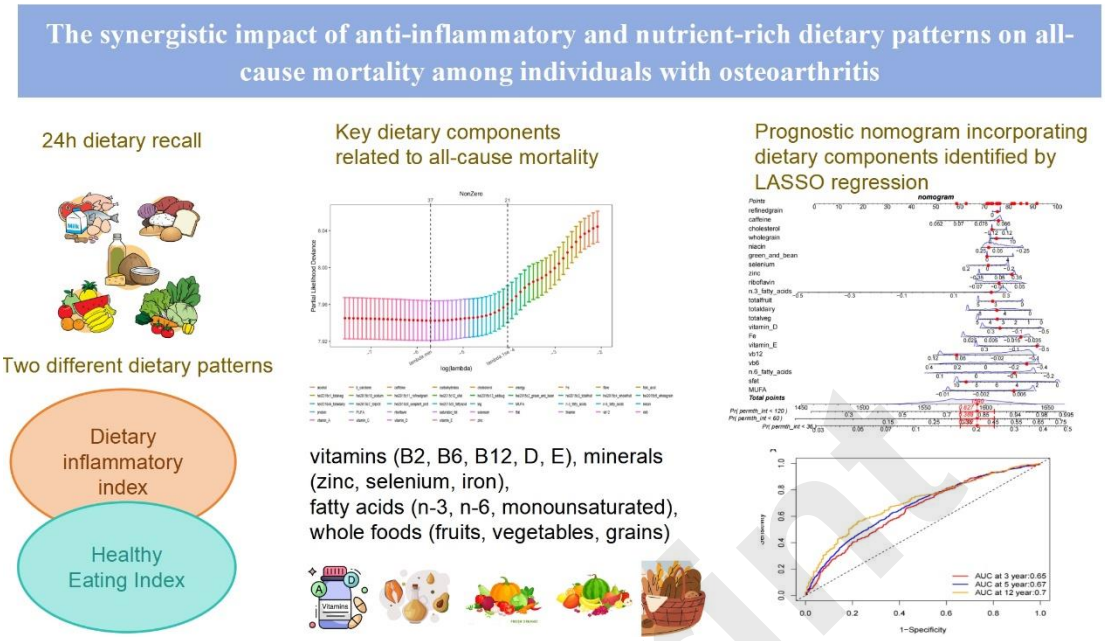
Results: A healthy, anti-inflammatory diet (high HEI-2015, low DII) was associated with a 14% lower mortality risk (HR: 0.86, 95% CI: 0.75–1.00, p-trend = 0.045) compared to an unhealthy, pro-inflammatory diet. LASSO regression highlighted 21 key dietary factors, including vitamins (B2, B6, B12, D, E), minerals (zinc, selenium, iron), fatty acids (n-3, n-6, monounsaturated), and whole foods (fruits, vegetables, grains). The nomogram showed reliable predictive accuracy (AUC: 0.65 at 3 years, 0.70 at 12 years). Subgroup analyses indicated stronger effects in non-smokers (HR: 0.79, 95% CI: 0.65–0.97).

Conclusion: Adopting a healthy, anti-inflammatory dietary pattern can reduce mortality rates in individuals with arthritis, with specific micronutrients and food groups playing a critical role. Dietary interventions are beneficial for OA management, highlighting the need for further longitudinal and clinical research to establish causal relationships.

Keywords: Osteoarthritis, dietary patterns, Healthy Eating Index, Dietary

Inflammatory Index, mortality, NHANES

Graphical abstract



1. Introduction

Osteoarthritis (OA) is a common degenerative joint disorder characterized by progressive cartilage breakdown, osteophyte formation, and chronic synovial inflammation, leading to persistent pain, stiffness, and reduced mobility, significantly impacting daily function and well-being[1-3]. It impacts about 303 million people worldwide, with prevalence rising due to aging populations and increasing obesity rates [4]. OA affects approximately 30.8 million adults, accounting for 13.4% of the adult population, making it one of the most common chronic joint conditions[5]. Furthermore, OA is frequently associated with multimorbidity, including cardiovascular diseases,

metabolic disorders such as diabetes, and systemic low-grade inflammation. These comorbidities not only exacerbate disease progression but also contribute to an increased risk of mortality among affected individuals [6-8].

Dietary factors significantly influence the onset, progression, and clinical outcomes of OA[9]. Consuming foods abundant in antioxidants, omega-3 fatty acids, and dietary fiber has been shown to support joint health by mitigating systemic inflammation and oxidative stress[10-12]. For example, the Mediterranean diet—renowned for its anti-inflammatory effects—has demonstrated associations with symptomatic relief and delayed disease progression in OA patients [13].

Dietary quality and inflammation are measured using the Healthy Eating Index (HEI-2015) and Dietary Inflammatory Index (DII). The HEI-2015 evaluates food group balance and nutrient intake, with higher scores linked to lower risks of cancer, cardiovascular disease, and mortality[14]. Conversely, the DII measures the inflammatory properties of an individual's diet, categorizing it as either pro-inflammatory or anti-inflammatory. Elevated DII scores have been associated with higher mortality risks, particularly from cardiovascular disease, cancer, and metabolic syndrome[15, 16]. In non-OA populations, higher HEI-2015 scores and lower DII scores are associated with reduced long-term mortality. However, the application of these dietary indices in OA patients and their impact on mortality risk remain underexplored, particularly due to a lack of evidence from large-scale, representative cohorts.

This study aims to explore potential associations between dietary patterns, as

measured by HEI-2015 and DII, and all-cause mortality in OA patients using NHANES 2007–2018 data. We hypothesize that higher HEI-2015 and lower DII scores may be associated with lower mortality risk, though the observational design limits causal inferences. These exploratory findings aim to inform future research on dietary interventions for OA management.

2. Materials and methods

2.1 Study design and population

NHANES, a nationally representative cross-sectional survey by the CDC's NCHS, assesses the health and nutrition of the U.S. population. Using a stratified, multistage probability design, it collects data biennially from ~10,000 participants via interviews, physical exams, and lab tests, supporting public health research and policy[17].

This study utilized data from the 2007–2018 NHANES, initially including 59,842 respondents. First, individuals under 18 years of age (n=23,262) were excluded, leaving 36,580 adult participants. Subsequently, those diagnosed with non-osteoarthritis conditions or with unclear arthritis etiology (n=32,938) and those with missing dietary data (n=624) were excluded, resulting in 3,018 eligible rheumatoid arthritis patients. Finally, participants with missing survival data (n=6) were excluded, yielding 3,012 subjects for analysis (Figure 1).

2.2 Definition of osteoarthritis

OA was identified using the NHANES Medical Conditions Questionnaire (MCQ). Participants were asked, "Have you ever been told by a doctor or other health

professional that you had arthritis?" (Question code: MCQ160A). Those responding "yes" were further asked to specify the type of arthritis (MCQ190/191/195: "Which type of arthritis was it?"), with response options including osteoarthritis, rheumatoid arthritis, and others. Only participants reporting a diagnosis of osteoarthritis were included in this study[18].

2.3 Dietary assessment

Dietary intake data from NHANES (2007–2018) were collected via 24-hour dietary recall interviews under the What We Eat in America initiative. Trained professionals used the Automated Multiple-Pass Method to ensure accurate recall of all foods and beverages consumed from midnight to midnight the previous day, including portion sizes and preparation methods. Each participant completed two non-consecutive recalls: one in-person at the Mobile Examination Center with measurement aids (e.g., cups, spoons, visual models) and one by telephone 3–10 days later with a provided food measurement guide. Mean consumption values from both recalls were used to reduce variability, with single-day data included for participants with only one recall.

The HEI-2015 was used to assess overall diet quality in relation to the 2015–2020 Dietary Guidelines for Americans[19]. The HEI-2015 evaluates diet quality based on the 2015–2020 Dietary Guidelines for Americans, comprising 13 components (total score: 0–100). Key adequacy components include: (1) hei2015c1_totalveg (total vegetables, 0–5 points), which measures intake of all vegetables (excluding legumes

and starchy vegetables like corn) in cup equivalents per 1,000 kcal, with higher intake yielding higher scores; (2) hei2015c2_green_and_bean (greens and beans, 0–5 points), which scores intake of dark green vegetables (e.g., spinach, broccoli) and legumes (e.g., soybeans, lentils), encouraging their consumption as key healthy diet components; (3) hei2015c3_totalfruit (total fruits, 0–5 points), which includes whole fruits and fruit juices, with higher intake scoring higher but prioritizing whole fruits to limit added sugars; and (4) hei2015c4_wholefruit (whole fruits, 0–5 points), which specifically evaluates non-juice fruit intake to promote direct fruit consumption and minimize added sugar intake. Other adequacy components include whole grains, dairy, total protein foods, seafood and plant-based proteins, and fatty acids ratio. Moderation components include refined grains, sodium, added sugars, and saturated fats. Higher HEI-2015 scores indicate better diet quality.

The DII was calculated to evaluate the inflammatory potential of the diet, which has been associated with chronic disease outcomes, including mortality[20]. The Dietary Inflammatory Index (DII) quantifies the inflammatory impact of 45 dietary components, based on literature linking diet to inflammation markers (e.g., C-reactive protein, interleukin-6). This study used 28 NHANES components, including energy, macronutrients (carbohydrates, proteins, fats, cholesterol), micronutrients (vitamins A, B1, B2, B6, B12, C, D, E, niacin, folate, iron, magnesium, selenium, zinc), and others (caffeine, alcohol). DII scores were calculated by standardizing intake into z-scores using a global reference database, converting to percentiles, centering with (percentile × 2) − 1, and multiplying by component-specific inflammatory effect scores from

literature. Component scores were summed for the overall DII score.

2.4 Ascertainment of mortality

Mortality status in the NHANES was determined through probabilistic linkage with the National Death Index (NDI), a comprehensive database of death records maintained by the NCHS. Additional data sources, including Social Security Administration records and Medicare/Medicaid Services data, were used to enhance linkage accuracy. NHANES participants provided personal identifiers (e.g., name, Social Security Number, date of birth, sex, and state of residence) during the survey, which were used to match records with NDI entries via a probabilistic algorithm. The linked dataset included vital status, date of death (month and year), and cause of death coded. Follow-up extended from the NHANES examination date to December 31 of 2019.

2.5 Assessment of covariates

The NHANES collected comprehensive covariate data through structured questionnaires, clinical examinations, and laboratory tests to adjust for potential confounding factors in mortality analyses. These covariates encompassed demographic factors (age as a continuous variable, self-reported gender, race/ethnicity categorized as Non-Hispanic White, Non-Hispanic Black, Hispanic, or Other, and marital status classified as married, widowed, divorced, separated, never married, or living with a partner), socioeconomic indicators (family income level via the Poverty Income Ratio

and educational attainment as less than high school, high school graduate, or college or higher), lifestyle and behavioral factors (smoking status as never, former, or current smoker, alcohol consumption as none, mild, moderate, or heavy based on dietary interviews, and physical activity measured in MET-minutes per week), medical history and health status (diabetes defined by self-reported diagnosis, fasting glucose $\geqslant$126 mg/dL, HbA1c $\geqslant$6.5%, or antidiabetic medication use, and hypertension identified by self-reported diagnosis, blood pressure $\geqslant$ 140/90 mmHg, or antihypertensive medication use), and nutritional and metabolic factors (dietary supplement use in the past 30 days, total caloric intake from 24-hour dietary recalls, and estimated glomerular filtration rate calculated using the CKD-EPI equation incorporating serum creatinine, age, gender, and race)[21] (Supplementary materials).

2.6 Statistical analysis

All statistical analyses were performed utilizing data from the National Health and Nutrition Examination Survey (NHANES). To ensure the accuracy and generalizability of the findings, appropriate survey weights were applied to adjust for the complex, stratified, multistage probability sampling design inherent in NHANES. Additionally, first-day dietary recall weights were incorporated for dietary data analysis to produce nationally representative estimates. Continuous variables were summarized as means ± standard errors (SE) when normally distributed, while non-normally distributed variables were expressed as medians with interquartile ranges (IQR). Categorical variables were reported as weighted frequencies and percentages to reflect their

distribution accurately. Group comparisons were assessed using weighted analysis of variance (ANOVA) for continuous measures and weighted chi-square tests for categorical variables. To address missing covariates within the NHANES 2007–2018 dataset, the Multivariate Imputation by Chained Equations (MICE) method was employed, ensuring robust handling of incomplete data through multiple imputation techniques. (Supplemental figure1 and 2).

The HEI-2015 and DII were categorized into quartiles: HEI-2015 as Q1 (≤47.17), Q2 (47.17–55.93], Q3 (55.93–66.10], Q4 (>66.10); DII as Q1 (≤-0.089), Q2 (-0.089–1.42], Q3 (1.42–2.77], Q4 (>2.77). Dietary patterns were defined based on the median values of the HEI-2015, and DII as follows: Unhealthy and Pro-Inflammatory (HEI-2015 ≤ 55.93947, DII > 1.424381), Healthy and Pro-Inflammatory (HEI-2015 > 55.93947, DII > 1.424381), Unhealthy and Anti-Inflammatory (HEI-2015 ≤ 55.93947, DII ≤ 1.424381), and Healthy and Anti-Inflammatory (HEI-2015 > 55.93947, DII ≤ 1.424381).Weighted Cox proportional hazards regression models were used to assess the association between dietary patterns (HEI-2015, DII, and their composite effects) and all-cause mortality, with hazard ratios (HRs) and 95% confidence intervals (CIs). The p-value for trend was calculated to evaluate dose-response relationships.

Subgroup analyses were conducted to evaluate effect modification by key demographic and clinical variables with interaction p-values calculated to assess heterogeneity across subgroups. Sensitivity analyses mitigated reverse causation by excluding participants who died within the first year of follow-up. The relationships between dietary indices (HEI-2015 and DII) and mortality were examined using

restricted cubic spline (RCS) models to assess non-linear associations, while Least Absolute Shrinkage and Selection Operator (LASSO) regression, with 10-fold cross-validation to determine the optimal tuning parameter (λ), identified influential dietary factors linked to mortality. A prognostic nomogram, developed from LASSO-selected dietary components, predicted mortality risk, with predictive accuracy evaluated using the area under the receiver operating characteristic curve (AUC) and time-dependent ROC analysis. Participants were stratified into high- and low-risk groups based on the median risk score from the nomogram, and Kaplan-Meier survival curves compared mortality risk between these groups. All statistical analyses were performed using R software (version 4.2.0), with a two-sided p-value <0.05 considered statistically significant.

3. Results

3.1 Patient characteristics

A cohort of 3,012 osteoarthritis patients (63.73% female, median age 63 years, IQR: 54–72) was stratified into four dietary pattern groups: Unhealthy and Pro-Inflammatory (n=1,070), Healthy and Pro-Inflammatory (n=548), Unhealthy and Anti-Inflammatory (n=427), and Healthy and Anti-Inflammatory (n=967). Demographic and clinical characteristics, as detailed in Table 1, showed significant variations ($p < 0.05$) across groups for age, sex, race/ethnicity, marital status, family income poverty ratio, education level, smoking status, alcohol consumption, physical activity (MET scores), diabetes mellitus, dietary supplement use, and total energy intake. The Healthy and

Anti-Inflammatory group had the highest median family income poverty ratio (4.12, IQR: 2.23–5.00) and the largest proportion of college-educated individuals (74.69%), while the Unhealthy and Anti-Inflammatory group had the highest mean daily energy intake (2503.04 ± 46.79 kcal). No significant difference was observed in hypertension prevalence across groups ($p = 0.5$).

3.2 Impact of a healthy and anti-inflammatory diet on mortality rates in individuals with OA

Table 2 illustrates the correlations between dietary patterns and mortality risk in osteoarthritis patients, evaluating the DI) and HEI-2015 stratified by quartiles, which showed no statistically significant association between lower DII scores (indicating reduced inflammation) or higher HEI-2015 scores (reflecting better diet quality) and decreased long-term mortality risk, with hazard ratios in Model 2 of 1.11 (95% CI: 0.94–1.30, p-trend = 0.109) for DII and 0.91 (95% CI: 0.77–1.07, p-trend = 0.13) for HEI-2015. Participants were classified into four groups based on median DII and HEI-2015 values, and after comprehensive adjustment for confounders in Model 2—including age, gender, race, marital status, family income, education, smoking status, alcohol consumption, physical activity, diabetes, hypertension, supplement use, total caloric intake, and estimated glomerular filtration rate—those following a Healthy and Anti-Inflammatory Diet exhibited a 14% reduction in long-term mortality risk compared to those with an Unhealthy and Pro-Inflammatory Diet (HR: 0.86, 95% CI: 0.75–1.00, p-trend = 0.045). Restricted Cubic Spline analysis revealed no significant

nonlinear associations, indicating a consistent trend across the observed ranges of dietary scores (Figure 2).

3.3 Subgroup analyses

Subgroup analyses, as detailed in Table 3, were conducted to evaluate variations in the association between composite dietary patterns and mortality across demographic and clinical factors. No statistically significant interaction effects were found for age, gender, race/ethnicity, alcohol consumption, hypertension, or diabetes mellitus (p-interaction > 0.05). However, a significant interaction was observed for smoking status (p-interaction = 0.04), with never-smokers adhering to a Healthy and Anti-Inflammatory dietary pattern showing a significantly lower mortality risk compared to those following an unhealthy dietary pattern (HR: 0.79, 95% CI: 0.65–0.97, p-trend = 0.04).

3.4 Key dietary factors linked to mortality

Through LASSO regression analysis (Figure 3), key dietary components associated with the long-term mortality risk of OA patients were identified. Figure 3A illustrates the coefficient shrinkage trajectories of 41 dietary variables, while Figure 3B determines the tuning parameter (λ) via ten-fold cross-validation, selecting 1 standard deviation, ultimately identifying 21 key dietary factors: caffeine, cholesterol, niacin, selenium, zinc, vitamin B2, n-3 fatty acids, vitamin D, iron, vitamin E, vitamin B6, vitamin B12, n-6 fatty acids, monounsaturated fatty acids, refined grains, whole grains,

greens and beans, total fruits, whole fruits, total vegetables, and saturated fats. Figure 4 presents a prognostic nomogram constructed based on the LASSO regression results, further analyzing the relationship between intake and mortality. The area under the receiver operating characteristic (ROC) curve indicates: the AUC at 3 years is 0.65, at 5 years is 0.67, and at 12 years is 0.70, with predictive accuracy increasing over time (Figure 5A). Time-dependent AUC shows high predictive accuracy for long-term mortality (10 years) (Figure 5B).

A dietary risk score was computed for each participant in the study, with individuals scoring below the median categorized as "low risk" and those above the median designated as "high risk." Subsequent Kaplan-Meier survival analysis demonstrated a statistically significant increase in long-term mortality rates among high-risk patients when compared to their low-risk counterparts (Figure 6).

3.5 Sensitivity analysis

Individuals who passed away within the initial year of follow-up were systematically excluded to minimize potential bias. The findings demonstrated that consistent adherence to a health-promoting, anti-inflammatory dietary pattern was associated with a statistically significant 14% reduction in overall mortality risk (adjusted HR: 0.86; 95% CI: 0.75–0.99). This protective association remained robust even after comprehensive adjustment for all relevant confounding variables, thereby reinforcing the reliability and validity of the analytical model (Table 4).

4. Discussion

This study evaluates the combined effect of HEI-2015 and DII on mortality in osteoarthritis patients, finding that a healthy, anti-inflammatory diet (high HEI-2015, low DII) is associated with a 14% lower mortality risk (HR=0.86, 95% CI: 0.75–1.00, p-trend=0.045). LASSO regression identified 21 key dietary predictors, and a nomogram showed reliable prognostic accuracy (AUC=0.70 at 12 years). Neither HEI-2015 nor DII alone was significantly linked to mortality.

Recent studies link dietary patterns to OA outcomes. The Western dietary pattern, rich in red meat, processed foods, and refined grains, is consistently associated with increased OA progression. A large-scale cohort study from the Osteoarthritis Initiative (n=2,842, mean age: 60.5 years) found that adherence to a Western diet elevated the risk of radiographic knee OA progression (Kellgren and Lawrence grade $\geqslant$2) over 72 months (HR = 1.69, 95% CI: 1.13 – 2.52), while a prudent dietary pattern, high in fruits, vegetables, whole grains, and lean proteins, was linked to a reduced risk (HR = 0.70, 95% CI: 0.50–0.98)[22]. These findings are supported by a systematic review of six cohort studies, which confirmed that prudent and Mediterranean diets mitigate OA symptom progression, whereas Western diets exacerbate clinical outcomes[23]. An umbrella review further emphasized the Mediterranean diet's protective effects on OA-related measures, such as pain and joint stiffness, attributed to its anti-inflammatory and antioxidant properties[24]. Additionally, a 2025 systematic review and meta-analysis of nine randomized controlled trials (n=898) evaluating dietary interventions—including energy-restricted, Mediterranean, low-fat, anti-inflammatory,

low-carbohydrate, and plant-based diets—demonstrated significant improvements in pain and physical function (SMD = -0.62, 95% CI: [-0.94, -0.30]), underscoring the potential of anti-inflammatory dietary strategies for effective OA management[25].

The DII associates higher scores (pro-inflammatory diets rich in saturated fats and refined carbohydrates) with worse OA outcomes. A longitudinal study (n=1,127) from the Osteoarthritis Initiative found higher DII scores linked to lower quality of life (QoL), with increased odds of low physical-low psychological QoL (OR=1.163, p=0.014) or low physical-high psychological QoL (OR=1.131, p=0.013), and reduced overall QoL (β=-0.117, p<0.001)[26]. A cross-sectional study (n=4,358) found a dose-dependent link between higher DII scores and increased radiographic symptomatic knee OA prevalence, rising from 24.0% in the lowest quartile to 35.4% in the highest (p<0.0001), with an adjusted odds ratio of 1.40 (95% CI: 1.14–1.72, p=0.002) for the highest versus lowest quartile[27].

The HEI-2015 shows limited direct evidence linking it to OA but suggests benefits through its inverse correlation with the DII. A study of 937 White postmenopausal women found higher HEI-2015 scores correlated with lower DII scores (r = -0.347, p < 0.001) and reduced waist circumference (r = -0.152, p < 0.001), a key OA risk factor. Women in the highest HEI-2015 quartile had lower waist circumference (80.73 cm) than the lowest (85.89 cm, p < 0.001), with HEI-2015 independently predicting waist circumference (B = -0.168, p < 0.001). Given DII's link to OA symptoms, higher HEI-2015 scores may indirectly mitigate OA outcomes by reducing inflammation and obesity risk. However, the lack of direct HEI-2015-OA studies necessitates further

longitudinal research[28] .

This research leverages several key strengths to ensure robust and reliable findings. Utilizing data from the 2007–2018 NHANES with its stratified, multistage probability sampling design, the study achieves national representativeness, allowing generalization to the U.S. adult population with osteoarthritis. Comprehensive dietary assessment through two non-consecutive 24-hour dietary recalls provides high-quality data for calculating the HEI-2015 and DII. Advanced statistical techniques, including LASSO-Cox regression and a prognostic nomogram, enhance the precision and predictive accuracy of the analysis. Additionally, the study accounts for an extensive range of covariates—demographic, lifestyle, and clinical factors—to minimize confounding bias, while subgroup and sensitivity analyses further strengthen the robustness and clinical relevance of the findings.

Despite its strengths, this study has several limitations. The reliance on self-reported OA diagnoses from the NHANES Medical Conditions Questionnaire may introduce misclassification bias, as diagnoses were not verified through clinical or radiographic methods. The use of 24-hour dietary recalls captures short-term intake, which may not fully represent long-term dietary patterns, potentially affecting the accuracy of HEI-2015 and DII scores. As an observational study, it cannot establish causality between dietary patterns and mortality risk. Furthermore, the DII calculation was restricted to 28 of the 45 possible components due to limited data availability in NHANES, excluding parameters such as certain bioactive compounds (e.g., flavonoids, spices) that may influence inflammatory potential. This incomplete coverage may

reduce the DII's sensitivity and accuracy in capturing the full spectrum of dietary inflammatory effects, potentially underestimating or misrepresenting associations with mortality. Furthermore, the reliance on 24-hour dietary recalls, while validated for short-term intake, may not adequately reflect long-term dietary patterns due to day-to-day variability in food consumption. This could introduce measurement error in both HEI-2015 and DII scores, affecting the precision of observed associations. Future research should incorporate comprehensive DII components and longitudinal dietary assessments, such as food frequency questionnaires, to enhance the robustness and reliability of dietary pattern analyses in osteoarthritis cohorts.

Conclusion

This NHANES 2007–2018 study shows that a healthy, anti-inflammatory diet (high HEI-2015, low DII) is associated with reduced mortality risk in osteoarthritis patients. Key dietary factors include vitamins, minerals, fatty acids, and whole foods. The prognostic nomogram showed reliable accuracy. Further research is needed to explore causal links and optimize dietary recommendations.

Author declarations

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Authors' contributions

Fuyue Yang, Yan Wang, and Qingyuan Li contributed significantly to the study design, data analysis, and initial drafting of the manuscript. Tong Feng and Wenjing Dai provided critical revisions to the document, ensuring its accuracy and coherence, and approved the final version for submission. All authors thoroughly reviewed and endorsed the manuscript prior to its submission.

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Availability of data and materials

The survey data are publicly available on the internet for data users and researchers throughout the world (www.cdc.gov/nchs/nhanes/).

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None

Declarations

Competing interests

The authors declare no conflict of interest.

Consent for publication

Not applicable

Ethics approval and consent to participate

The Institutional Review Board (IRB) of the National Center for Health Statistics (NCHS) rigorously reviewed and approved all study protocols associated with the National Health and Nutrition Examination Survey (NHANES). Prior to participation, written informed consent was secured from all enrolled individuals. For participants under the age of 18, consent was obtained from legally authorized proxies or guardians. The research adhered strictly to the ethical principles established in the 1964 Declaration of Helsinki, ensuring compliance with all relevant amendments and contemporary ethical guidelines for human subject research.

Declaration of generative AI and AI-assisted technologies in the writing process

In the process of preparing this work, the author(s) employed GPT-4, an advanced AI language model, to assist with linguistic refinement and stylistic improvements. Following the use of this tool, the author(s) conducted a thorough review, made necessary revisions, and ensured the accuracy, originality, and integrity of the content. The author(s) assume complete responsibility for the final version of this publication, including its scholarly validity and adherence to ethical standards.

Clinical trial number: not applicable.

427 Table 1 Characteristic of study sample.

Characteristic	Unhealthy and Pro-Inflammatory diet N = 1070	Healthy and Pro-Inflammatory diet N = 548	Unhealthy and Anti-Inflammatory diet N = 427	Healthy and Anti-Inflammatory diet N =967	p-value
Age, years	60.00(52.00,71.00)	67.00(58.00,75.00)	61.00(51.00,69.00)	65.00(58.00,73.00)	< 0.001
Sex					< 0.001
Male	339(30.13)	114(17.67)	230(52.42)	390(41.03)	
Female	731(69.87)	434(82.33)	197(47.58)	577(58.97)	
Race/Ethnicity					< 0.001
Non-Hispanic Black	209(9.70)	95(6.99)	59(4.92)	122(4.85)	
Non-Hispanic White	636(77.76)	314(82.50)	286(86.32)	635(84.33)	
Mexican American	67(2.89)	49(3.72)	42(3.30)	60(2.19)	
Other Hispanic	70(2.63)	57(2.81)	17(1.08)	76(3.14)	
Other Race - Including Multi-Racial	88(7.01)	33(3.98)	23(4.37)	74(5.49)	
Marital					0.004
Never married	98(8.01)	31(5.45)	38(9.38)	51(5.00)	
Married/ Living with partner	586(61.10)	289(60.75)	272(68.67)	617(68.58)	
Divorced/ Widowed/ Separated	386(30.89)	228(33.80)	117(21.95)	299(26.42)	
Family income poverty ratio	2.64(1.52,4.71)	2.95(1.54,4.92)	3.40(1.84,5.00)	4.12(2.23,5.00)	< 0.001
Education					< 0.001
Less than high school	93(4.68)	61(4.73)	19(2.85)	42(1.76)	
High school or equivalent	435(39.81)	204(36.98)	146(31.17)	258(23.55)	
College and above	542(55.52)	283(58.29)	262(65.98)	667(74.69)	
Smoking status					< 0.001
Never	448(44.32)	317(53.96)	186(43.72)	500(52.01)	
Former	345(31.30)	167(31.45)	167(40.70)	385(39.22)	
Now	277(24.38)	64(14.60)	74(15.59)	82(8.77)	
Drinking status					< 0.01
Never	132(10.25)	107(14.68)	32(5.42)	111(9.13)	
Former	262(20.46)	113(17.05)	88(17.06)	155(13.63)	
Mild	410(42.12)	229(45.85)	197(47.50)	508(54.98)	
Moderate	153(14.69)	57(11.88)	59(16.45)	131(15.36)	
Heavy	113(12.49)	42(10.55)	51(13.57)	62(6.90)	
MET scores, min/week	3201.08 (1440.00,5063.27)	2271.89 (1000.00,3532.35)	2880.00 (900.00,5280.00)	2460.00 (1080.00,4320.00)	0.001
DM					0.01
No	738(76.32)	359(71.35)	303(73.62)	740(81.61)	

Yes	332(23.68)	189(28.65)	124(26.38)	227(18.39)	
Hypertension					0.5
No	333(35.01)	165(36.48)	145(37.06)	332(39.80)	
Yes	737(64.99)	383(63.52)	282(62.94)	635(60.20)	
Use of Supplement					< 0.001
No	421(35.65)	168(24.29)	125(24.21)	205(21.50)	
Yes	649(64.35)	380(75.71)	302(75.79)	762(78.50)	
Energy,kcal	1715.77±24.41	1387.61±23.24	2503.04±46.79	2104.70±29.80	< 0.001

Abbreviations: MET: Metabolic Equivalent of Task; DM: diabetes mellitus.

Table 2 Relationship between dietary habits and mortality in osteoarthritis patients

Outcomes		**Crude Model**	**Model 1**	**Model 2**
		HR (95%CI)	**HR (95%CI)**	**HR (95%CI)**
HEI-2015	Continuous	1.00(0.99,1.00)	1.00(0.99,1.00)	1.00(0.99,1.00)
	Categories			
	Q1 (≤47.17)	Ref.	Ref.	Ref.
	Q2 (47.17,55.93]	1.10(0.98,1.24)	1.08(0.95,1.23)	1.08(0.94,1.24)
	Q3 (55.93,66.10]	1.02(0.91,1.15)	0.99(0.87,1.11)	0.98(0.86,1.11)
	Q4 (＞66.10)	0.99(0.84,1.15)	0.92(0.78,1.09)	0.91(0.77,1.07)
	p for trend	0.646	0.206	0.13
DII	Continuous	1.00(0.97,1.03)	1.01(0.98,1.04)	1.03(1.00,1.06)
	Categories			
	Q1 (≤-0.089)	Ref.	Ref.	Ref.
	Q2 (-0.089,1.42]	1.04(0.92,1.18)	1.08(0.95,1.22)	1.10(0.97,1.24)
	Q3 (1.42,2.77]	1.13(0.99,1.29)	1.17(1.02,1.35)	1.22(1.06,1.40)
	Q4 (＞2.77)	0.97(0.84,1.11)	1.01(0.88,1.15)	1.11(0.94,1.30)
	p for trend	0.947	0.598	0.109
Composition effect	Categories			
	Unhealthy and Pro-Inflammatory diet	Ref.	Ref.	Ref.
	Healthy and Pro-Inflammatory diet	1.10(0.98,1.24)	1.08(0.95,1.23)	0.95(0.83,1.10)
	Unhealthy and Anti-Inflammatory diet	1.02(0.91,1.15)	0.99(0.87,1.11)	0.95(0.82,1.10)
	Healthy and Anti-Inflammatory diet	0.99(0.84,1.15)	0.92(0.78,1.09)	0.86(0.75,1.00))
	p for trend	0.646	0.206	0.045

Crude Model: no covariates were adjusted.

Model 1: Adjusted covariates for model 1 included age, gender, race, marital status, family income level, and educational level.

Model 2: Adjusted covariates for model 2 included the covariates for model 1 plus smoking status,

alcohol intake, physical activity, diabetes, hypertension, use of supplements, total Kal intake and eGFR.

HR, Hazard Ratio; 95%CI, 95% confidence interval; HEI: Healthy Eating Index; DII: Dietary Inflammatory Index

Table 3 Stratified analyses of the relationships of dietary patterns and mortality among OA patients.

Characteristics	**Unhealthy and Pro-Inflammatory diet** N = 1070	**Healthy and Pro-Inflammatory diet** N = 548	**Unhealthy and Anti-Inflammatory diet** N = 427	**Healthy and Anti-Inflammatory diet** N =967	***P* for trend**	***P* for interaction**
Age						0.68
<60	ref	0.92(0.72,1.17)	1.25(0.96,1.62)	1.02(0.80,1.31)	0.69	
≥60	ref	0.95(0.80,1.13)	0.74(0.59,0.91)	0.76(0.66,0.89)	<0.001	
Gender						0.35
Male	ref	1.08(0.81,1.44)	0.86(0.67,1.11)	0.84(0.66,1.07)	0.12	
Female	ref	0.93(0.79,1.09)	1.03(0.81,1.31)	0.87(0.74,1.04)	0.13	
Race/Ethnicity						0.28
Non-Hispanic Black	ref	0.72(0.48,1.07)	0.88(0.59,1.32)	0.47(0.32,0.69)	<0.001	
Non-Hispanic White	ref	0.98(0.83,1.14)	0.94(0.79,1.11)	0.86(0.74,1.00)	0.05	
Mexican American	ref	1.09(0.76,1.55)	1.58(0.88,2.81)	1.21(0.78,1.89)	0.39	
Other Hispanic	ref	0.68(0.43,1.06)	1.07(0.50,2.32)	1.23(0.86,1.76)	0.12	
Other Race - Including Multi-Racial	ref	1.26(0.65,2.44)	1.13(0.50,2.51)	0.98(0.60,1.62)	0.92	
Smoke status						0.04
Never	ref	0.76(0.60,0.95)	0.79(0.63,0.97)	0.79(0.65,0.97)	0.04	
Former	ref	1.16(0.87,1.55)	1.17(0.90,1.53)	0.91(0.73,1.15)	0.39	
Now	ref	1.22(0.86,1.74)	0.72(0.49,1.07)	0.92(0.65,1.30)	0.49	
Drinking status						0.18
Never	ref	0.91(0.56,1.48)	2.42(1.49,3.92)	1.13(0.75,1.69)	0.4	
Former	ref	1.01(0.73,1.40)	1.07(0.75,1.53)	0.87(0.62,1.22)	0.44	
Mild	ref	0.85(0.68,1.05)	0.73(0.60,0.90)	0.73(0.62,0.87)	<0.001	
Moderate	ref	1.14(0.77,1.70)	1.01(0.71,1.45)	0.96(0.66,1.38)	0.76	
Heavy	ref	1.51(0.88,2.59)	1.37(0.74,2.52)	1.36(0.93,1.98)	0.09	
Hypertension						0.24
No	ref	1.07(0.82,1.41)	1.10(0.86,1.40)	1.03(0.81,1.31)	0.85	
Yes	ref	0.89(0.75,1.05)	0.88(0.72,1.09)	0.77(0.65,0.91)	0.002	

DM					0.72
No	ref	0.95(0.81,1.10)	0.92(0.77,1.09)	0.85(0.73,1.00)	0.06
Yes	ref	1.03(0.75,1.42)	1.06(0.74,1.53)	0.92(0.72,1.17)	0.51

Adjusted covariates included age, gender, race, marital status, family income, education, smoking status, alcohol consumption, physical activity, diabetes mellitus (DM), hypertension, supplement use, total calorie intake, and eGFR, excluding stratified variables.

Table 4. Cox regression analysis of dietary habits and mortality in osteoarthritis patients excluding deaths within one year

Outcomes		**Crude Model**	**Model 1**	**Model 2**
		HR (95%CI)	**HR (95%CI)**	**HR (95%CI)**
Composition effect	Categories			
	Unhealthy and Pro-Inflammatory diet	Ref.	Ref.	Ref.
	Healthy and Pro-Inflammatory diet	1.00(0.86,1.15)	0.97(0.85,1.11)	0.95(0.83,1.10)
	Unhealthy and Anti-Inflammatory diet	1.03(0.89,1.19)	1.03(0.90,1.18)	0.95(0.82,1.10)
	Healthy and Anti-Inflammatory diet	0.95(0.83,1.09)	0.90(0.78,1.04)	0.86(0.75,1.00)
	p for trend	0.544	0.201	0.045

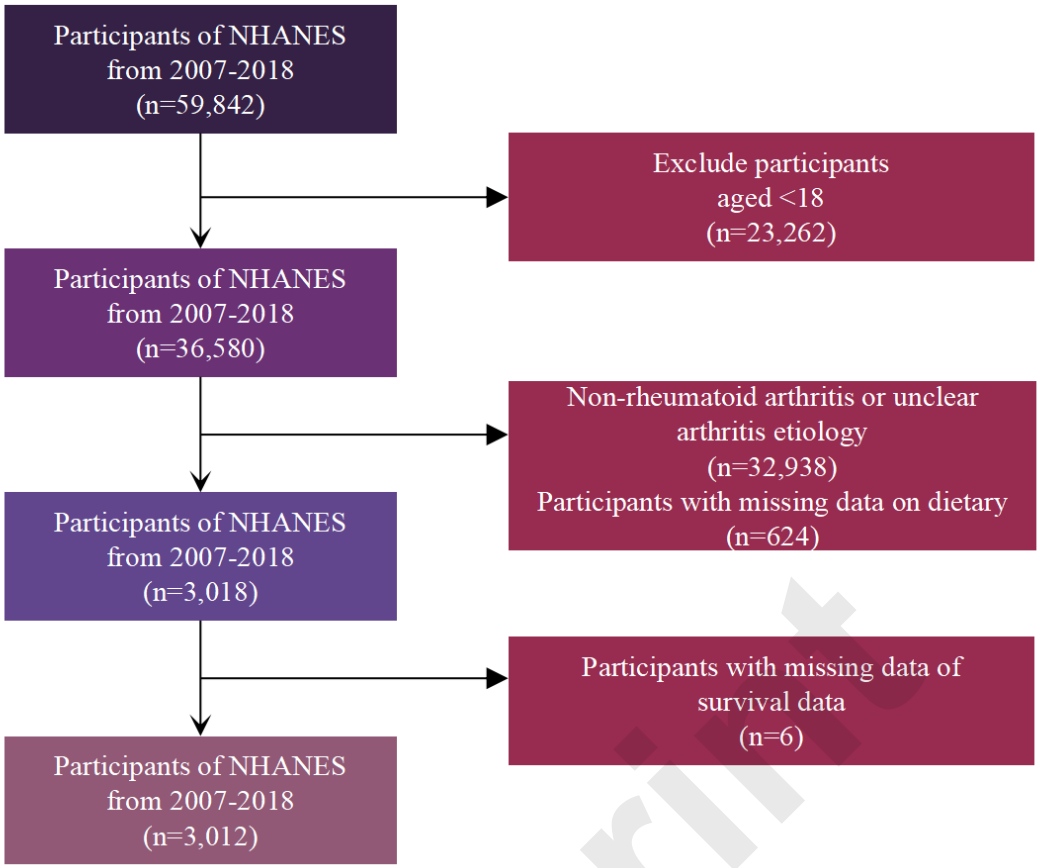

Figure 1. Flowchart for Selecting Eligible Study Participants

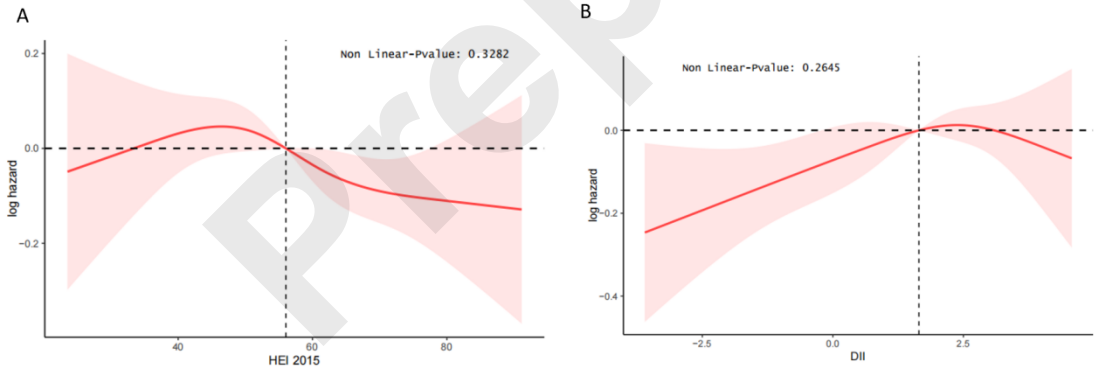

Figure 2. Restricted cubic spline (rcs) curves illustrating the relationship between dietary Indices and long-term mortality in osteoarthritis patients. (A) Dietary Inflammatory Index (DII). (B) Healthy Eating Index-2015 (HEI-2015).

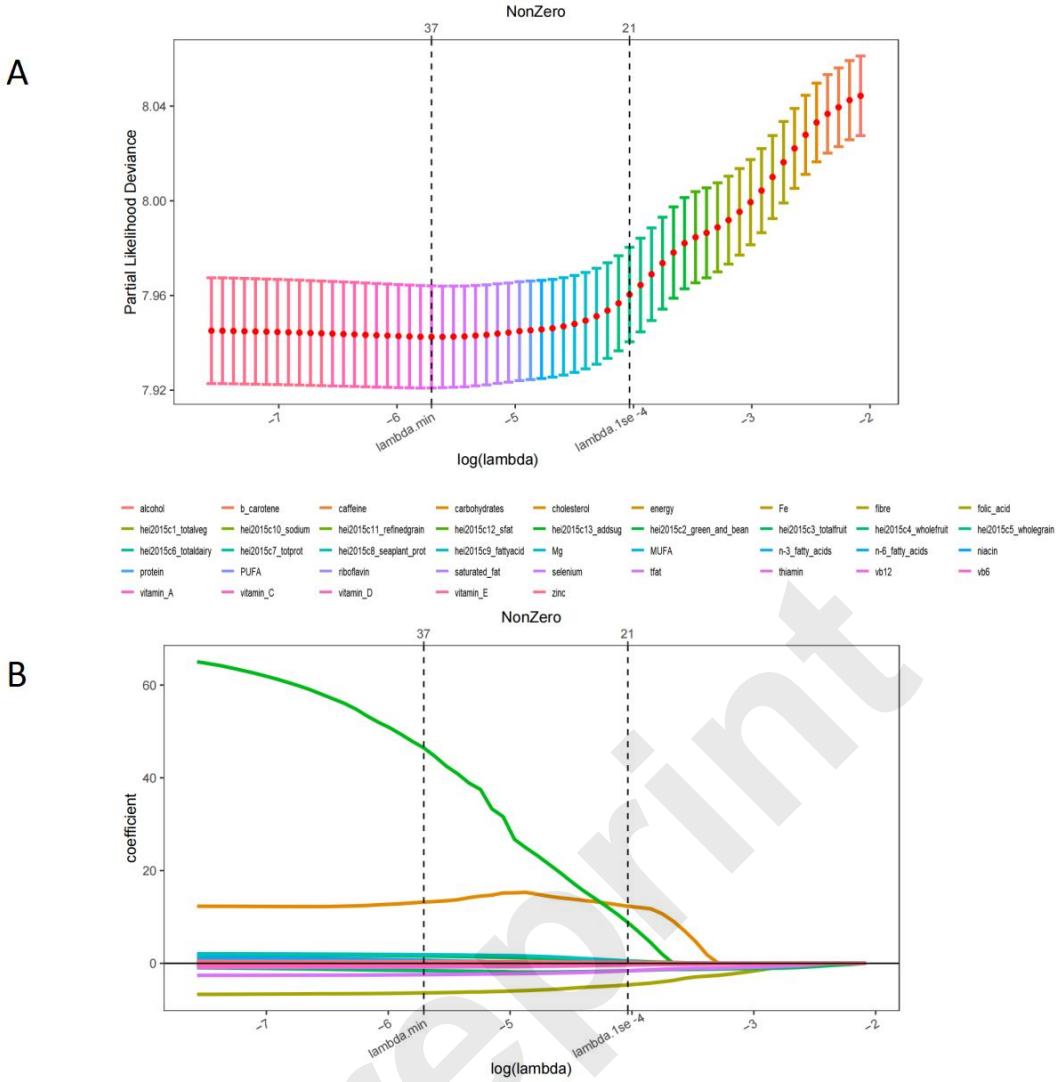

Figure 3. LASSO regression analysis for screening dietary factors linked to OA mortality. (A) Trajectory of coefficient shrinkage across 41 dietary variables. (B) Ten-fold cross-validation curve

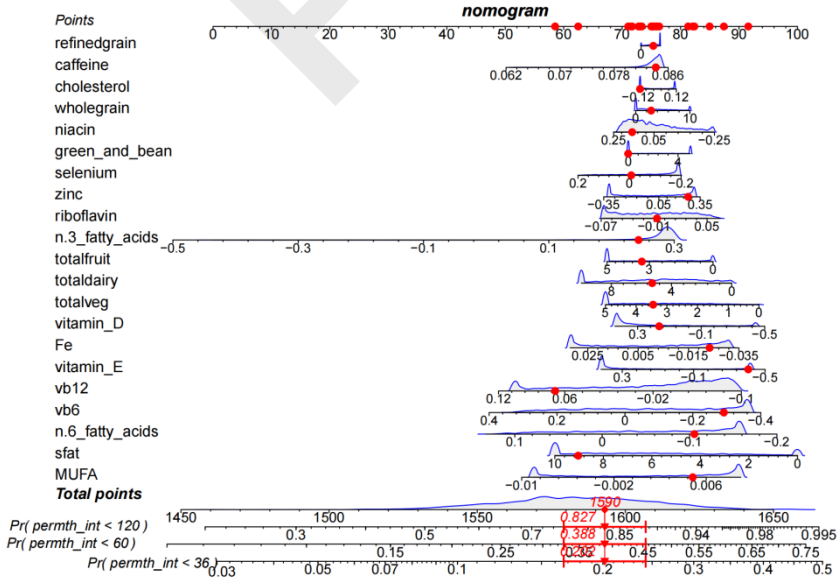

Figure 4. Prognostic nomogram incorporating dietary components identified by LASSO regression.

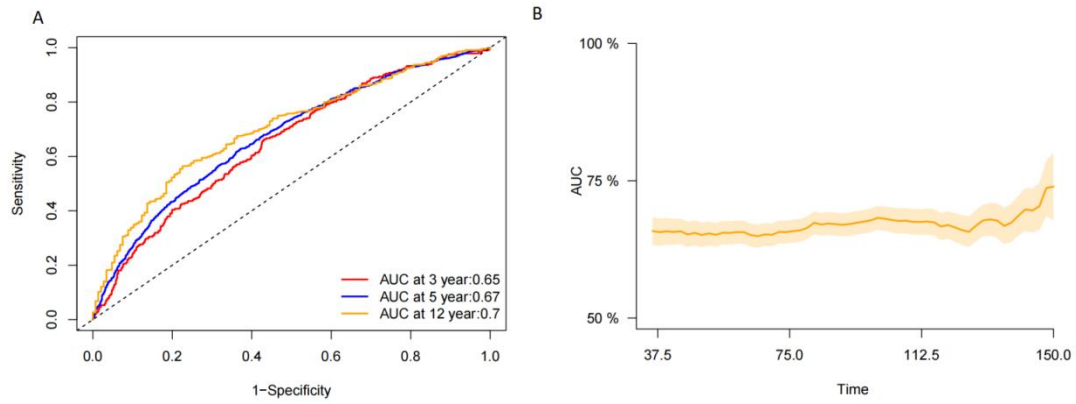

Figure 5. Predictive performance of the nomogram model for OA mortality. (A) ROC curve for all-cause mortality prediction. (B) Time-dependent ROC analysis for overall survival.

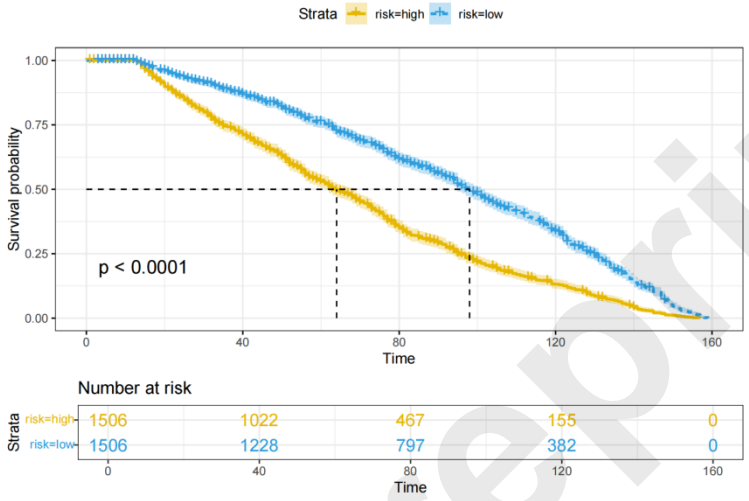

Figure 6. Kaplan-Meier estimates comparing mortality risk in patient subgroups identified by LASSO regression modeling.

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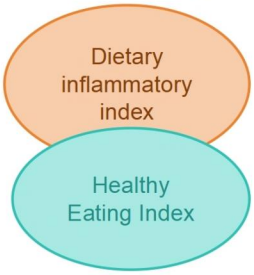
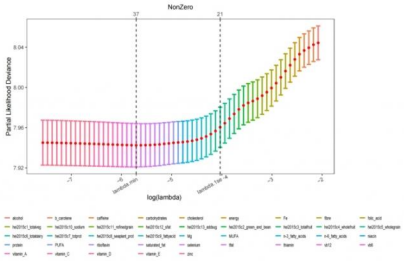
The synergistic impact of anti-inflammatory and nutrient-rich dietary patterns on all-cause mortality among individuals with osteoarthritis

24h dietary recall

Two different dietary patterns



Key dietary components related to all-cause mortality



vitamins (B2, B6, B12, D, E), minerals (zinc, selenium, iron),
fatty acids (n-3, n-n-6, monounsaturated),
whole foods (fruits, vegetables, grains)

Prognostic nomogram incorporating dietary components identified by LASSO regression