Predicting the depressive status using empirical dietary inflammatory index in patients with antineutrophil cytoplasmic antibody-associated vasculitis

Joo Hye Lee
Yonsei University College of Medicine
Jan-Di Yun
Yonsei University College of Medicine
Jeong Yeop Whang
Yonsei University College of Medicine
Jung Yoon Pyo
Yonsei University College of Medicine
Sung Soo Ahn
Yonsei University College of Medicine
Jason Jungsik Song
Yonsei University College of Medicine
Yong-Beom Park
Yonsei University College of Medicine
Sang-Won Lee (sangwonlee@yuhs.ac)
Yonsei University College of Medicine

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Abstract

Background: This study investigated whether the empirical dietary inflammatory index (eDII) score is associated with the inflammatory burden as well as the depressive status in patients with antineutrophil cytoplasmic antibody-associated vasculitis (AAV).

Methods: Eighty-four patients with AAV participated in this study. Birmingham vasculitis activity score (BVAS) and short-form 36-item Health Survey mental component summary (SF-36 MCS) were considered as indices assessing the inflammatory burden and depressive status, respectively. The eDII includes 16 food components and consists of three groups: -9 to -2, the low eDII group; -1 to +1, the moderate eDII group; and +2 to +10, the high eDII group. Furthermore, the lower eDII group includes both the low and moderate eDII groups.

Results: The median age was 64.5 years (36 men). The eDII scores inversely correlated with SF-36 MCS ($r = -0.298$, $P = 0.006$) but not with BVAS. SF-36 MCS significantly differ between the lower and higher eDII groups (69.7 vs. 56.7, $P = 0.016$), but not among the low, moderate, and high eDII groups. Additionally, when patients with AAV were divided into two groups according to the upper limit of the lowest tertile of SF-36 MCS of 55.31, patients in the higher eDII group exhibited a significantly higher risk for the lowest tertile of SF-36 MCS than those in the lower eDII group (RR 3.000).

Conclusion: We demonstrated for the first time that the eDII could predict the depressive status by estimating SF-36 MCS without utilising K-CESD-R $\geq$ 16 in patients with AAV.

Background

Various nutrients and foods have shown an association with the extent or acceleration of inflammation in chronic inflammatory diseases, and habitual dietary patterns may be involved in the modulation of inflammation [1]. The dietary inflammatory index (DII), which is the most widely used index, was developed based on these concepts [2, 3]. The DII showed an association with the inflammatory burden based on the levels of high-sensitivity C-reactive protein (CRP) in healthy volunteers in Korea and Japan [4, 5]. Moreover, the DII elicited an elevated inflammatory potential in patients with rheumatoid arthritis, as compared to the controls [6]. In addition to the inflammatory potential, the DII could predict depressive disorders in healthy adults as well as patients with chronic diseases [7–10], suggesting an important role of dietary nutrition in public mental health.

Antineutrophil cytoplasmic antibody (ANCA)-associated vasculitis (AAV) is a systemic vasculitis, that primarily affects small-sized vessels, including capillaries and adjacent arterioles and venules, and occasionally medium-sized arteries. AAV is characterised by necrotising vasculitis and/or granuloma formation and is composed of three typical subtypes, microscopic polyangiitis (MPA), granulomatosis with polyangiitis (GPA), and eosinophilic GPA (EGPA) according to clinical, laboratory, imaging, and histologic features [11, 12]. AAV is a representative chronic inflammatory disease that repeatedly exacerbated and improved over a long period, owing to its autoimmune disease mechanism [13]. In

addition to chronic inflammation, AAV is associated with mental health. A previous study revealed that the frequency of depressive disorders in Korean patients with AAV was 45.9% based on the Korean version of centre for epidemiologic studies depression scale-revised (K-CESD-R) ≥ 16, which was negatively correlated with the short-form 36-item Health Survey (SF-36) mental component summary (MCS) scores [14–16]. Therefore, it can be reasonably assumed that the DII may estimate the cross-sectional inflammatory burden as well as the depressive status in patients with AAV. However, there have been no reports regarding the clinical relevance of the DII in patients with AAV.

To overcome the difficulties in using the previous the DII due to many items, the empirical dietary inflammatory index (eDII), based on 16 food components was recently developed [17]. Hence, this study used the novel and convenient eDII questionnaire and investigated whether it is associated with the inflammatory burden as well as the depressive status in patients with AAV.

Methods

Subjects

The participants were randomly selected from those who were enrolled in the Severance Hospital ANCA-associated VasculitidEs (SHAVE) cohort and who agreed to participate in the study. The SHAVE cohort is a prospective and observational cohort, which began in November 2016, and includes patients with MPA, GPA, or EGPA. AAV diagnosis in all participants was confirmed at the Division of Rheumatology, Department of Internal Medicine, Yonsei University College of Medicine, and Severance Hospital. All participants fulfilled both the revised International Chapel Hill Consensus Conference Nomenclature of Vasculitides proposed in 2012, and the 2007 European Medicines Agency algorithms for AAV [11, 12]. During study enrolment, the patients were followed up for at least 3 months and had no concomitant serious medical conditions resulting in ambiguity in interpreting the results, such as malignancies and infectious diseases requiring hospitalisation [14, 18]. Although 89 patients with AAV volunteered to participate and provided informed consent, two patients were excluded due to concomitant serious infectious diseases and three patients due to consent withdrawal. Finally, 84 patients with AAV were included in this study. This study was approved by the Institutional Review Board of Severance Hospital (4-2016-0901) and conducted according to the Declaration of Helsinki. The patients' written informed consent was obtained from all patients.

Clinical data

All data were collected at the time of informed consent provision, filling out the eDII and SF-36 questionnaires, assessing AAV-specific indices, and performing blood tests. The demographic data included age and sex. Regarding the AAV-related variables, the AAV subtype, ANCA positivity status, AAV-specific indices, and clinical manifestations were recorded. In terms of acute-phase reactants reflecting the inflammatory status, erythrocyte sedimentation rate (ESR) and CRP levels were investigated along with routine laboratory tests [14, 18].

AAV-specific indices

The SF-36 MCS and SF-36 physical component summary (PCS) scores were considered as a functional status index [16], Birmingham vasculitis activity score (BVAS) as a vasculitis activity index [19], and vasculitis damage index (VDI) as a damage index [20]. In particular, SF-36 MCS and BVAS were considered as indices assessing the inflammatory burden and depressive status, respectively.

ANCA measurement

Myeloperoxidase (MPO)-ANCA and proteinase 3 (PR3)-ANCA were measured using the novel anchor-coated highly sensitive Phadia Elia (Thermo Fisher Scientific/Phadia, Freiburg, Germany) and human native antigens, using Phadia250 analyser. Immunoassays were used as the primary screening method for ANCA; however, when patients tested negative for ANCA by an antigen-specific assay but positive for perinuclear (P)-ANCA or cytoplasmic (C)-ANCA by an indirect immunofluorescence assay, they were considered to have MPO-ANCA or PR3-ANCA when AAV was strongly suspected based on the clinical and laboratory features [21].

Empirical dietary inflammation index

In the eDII, red meat, processed meat, organ meat, other fish, eggs, sugar-sweetened beverages, tomatoes, white rice, and bread/noodles are considered pro-inflammatory foods. On the other hand, leafy green vegetables, dark yellow vegetables, fruit juices, oily fish, coffee, tea, wine, beer, or other alcoholic beverages are considered anti-inflammatory foods. Differentiated scores are assigned from 0 to + 2 and from − 2 to 0 according to the frequency of consumption of pro-inflammatory foods and anti-inflammatory foods, respectively. The higher eDII score, the greater the inflammation [17].

Stratification

Patients were divided into three groups according to the eDII scores: -9 to -2, the low eDII group; -1 to + 1, the moderate eDII group; and + 2 to + 10, the high eDII group [17].

Statistical analyses

All statistical analyses were performed using IBM SPSS Statistics for Windows, version 26 (IBM Corp., Armonk, NY, USA). Continuous variables are expressed as medians with interquartile ranges, whereas categorical variables are expressed as numbers (percentages). The correlation coefficient (r) between the two variables was obtained using either the Pearson correlation analysis. Significant differences between two continuous variables were compared using the Mann-Whitney U test. Significant differences among more than three continuous variables were investigated using the Kruskal-Wallis test. The relative risk (RR) was analysed using contingency tables and the chi-square test. P-values less than 0.05 were considered statistically significant [14].

Results

Characteristics of participants

The median age of the participants was 64.5 years, and 36 patients were men. MPA was noted in 44 patients, GPA in 25 and EGPA in 15. MPO-ANCA (or P-ANCA) and PR3-ANCA (or C-ANCA) were detected in 31 (36.9%) and 7 patients (8.3%), respectively, whereas ANCA was not detected in 47 patients (56.0%). The median scores of SF-36 PCS, SF-36 MCS, BVAS, and VDI were 66.7, 62.3, 4.0, and 3.0, respectively. The most common clinical manifestation was pulmonary (54.8%), followed by otorhinolaryngological (46.4%) and renal (39.3%) manifestations. The median eDII score was 1.0. The laboratory results, including ESR and CRP are shown in Table 1.

Table 1
Characteristics of participants (N = 84)

Variables	Values
Demographic data	
Age (years)	64.5 (21.8)
Male sex (N, (%))	36 (42.9)
AAV Subtype (N, (%))	
MPA	44 (52.4)
EGPA	25 (29.8)
GPA	15 (17.9)
ANCA positivity (N, (%))	
MPO-ANCA (or P-ANCA) positivity	31 (36.9)
PR3-ANCA (or C-ANCA) positivity	7 (8.3)
Both ANCA positivity	1 (1.2)
ANCA negativity	47 (56.0)
AAV-specific indices	
SF-36 PCS	66.7 (31.9)
SF-36 MCS	62.3 (25.6)
BVAS	4.0 (4.0)
VDI	3.0 (3.0)
Clinical manifestations (N, (%))	
General	4 (4.8)
Cutaneous	9 (10.7)
Mucous membranous/Ocular	6 (7.1)

Values are expressed as a median (interquartile range, IQR) or N (%).

AAV: ANCA-associated vasculitis; ANCA: antineutrophil cytoplasmic antibody; MPA: microscopic polyangiitis; EGPA: eosinophilic granulomatosis with polyangiitis; GPA: granulomatosis with polyangiitis; MPO: myeloperoxidase; P: perinuclear; PR3: proteinase 3; C: cytoplasmic; SF-36: Short-Form 36-Item Health Survey; PCS: physical component summary; MCS: mental component summary; BVAS: Birmingham vasculitis activity score; VDI: vasculitis damage index; ESR: erythrocyte sedimentation rate; CRP: C-reactive protein; WBC: while blood cell; BUN: blood urea nitrogen; ALP: alkaline phosphatase; AST: aspartate aminotransferase; ALT: alanine aminotransferase; C3: complement 3; C4: complement 4; eDII: empirical dietary inflammatory index.

Variables	Values
Otorhinolaryngological	39 (46.4)
Pulmonary	46 (54.8)
Cardiovascular	9 (10.7)
Gastrointestinal	0 (0)
Renal	33 (39.3)
Nervous systemic	25 (29.8)
Laboratory results	
ESR (mm/hr)	13.0 (17.0)
CRP (mg/L)	1.3 (3.6)
WBC count (/mm^3)	6,790.0 (2,380.0)
Haemoglobin (g/dL)	13.2 (1.9)
Platelet count (× 1,000/mm^3)	237.0 (82.0)
Fasting glucose (mg/dL)	95.0 (13.5)
BUN (mg/dL)	19.9 (11.3)
Serum creatinine (mg/dL)	1.1 (0.9)
Total protein (g/dL)	6.8 (0.6)
Serum albumin (g/dL)	4.4 (0.4)
ALP (IU/L)	63.0 (33.0)
AST (IU/L)	19.0 (6.5)
ALT (IU/L)	16.0 (10.0)
Total bilirubin (mg/dL)	0.7 (0.4)
Complements	

Values are expressed as a median (interquartile range, IQR) or N (%).

AAV: ANCA-associated vasculitis; ANCA: antineutrophil cytoplasmic antibody; MPA: microscopic polyangiitis; EGPA: eosinophilic granulomatosis with polyangiitis; GPA: granulomatosis with polyangiitis; MPO: myeloperoxidase; P: perinuclear; PR3: proteinase 3; C: cytoplasmic; SF-36: Short-Form 36-Item Health Survey; PCS: physical component summary; MCS: mental component summary; BVAS: Birmingham vasculitis activity score; VDI: vasculitis damage index; ESR: erythrocyte sedimentation rate; CRP: C-reactive protein; WBC: while blood cell; BUN: blood urea nitrogen; ALP: alkaline phosphatase; AST: aspartate aminotransferase; ALT: alanine aminotransferase; C3: complement 3; C4: complement 4; eDII: empirical dietary inflammatory index.

Variables	Values
C3 (mg/dL)	117.1 (26.7)
C4 (mg/dL)	26.7 (10.1)
eDII score	1.0 (3.0)
Values are expressed as a median (interquartile range, IQR) or N (%).	
AAV: ANCA-associated vasculitis; ANCA: antineutrophil cytoplasmic antibody; MPA: microscopic polyangiitis; EGPA: eosinophilic granulomatosis with polyangiitis; GPA: granulomatosis with polyangiitis; MPO: myeloperoxidase; P: perinuclear; PR3: proteinase 3; C: cytoplasmic; SF-36: Short-Form 36-Item Health Survey; PCS: physical component summary; MCS: mental component summary; BVAS: Birmingham vasculitis activity score; VDI: vasculitis damage index; ESR: erythrocyte sedimentation rate; CRP: C-reactive protein; WBC: while blood cell; BUN: blood urea nitrogen; ALP: alkaline phosphatase; AST: aspartate aminotransferase; ALT: alanine aminotransferase; C3: complement 3; C4: complement 4; eDII: empirical dietary inflammatory index.	

Correlation

The correlation between the eDII scores and the values of the continuous variables was investigated. Among AAV-specific indices, the eDII scores showed a significant inverse correlation with SF-36 MCS (r = -0.298, P = 0.006). Furthermore, the eDII scores showed a correlation with SF-36 PCS and VDI but the difference was not statistically significant. Conversely, the eDII scores did not correlate with BVAS (r = 0.144, P = 0.192). Among the laboratory investigations, neither ESR nor CRP level was correlated with the eDII scores (Table 2).

Table 2
Correlation of the eDII scores with the values of continuous variables in patients with AAV

Variables	Correlation coefficient (r)	P-value
Demographic data		
Age (years)	-0.004	0.968
AAV-specific indices		
SF-36 PCS	-0.191	0.082
SF-36 MCS	-0.298	0.006
BVAS	0.144	0.192
VDI	0.202	0.066
Laboratory results		
ESR (mm/hr)	-0.063	0.590
CRP (mg/L)	-0.077	0.520
WBC count (/mm^3)	0.090	0.440
Haemoglobin (g/dL)	0.158	0.173
Platelet count (× 1,000/mm^3)	0.049	0.677
Fasting glucose (mg/dL)	0.077	0.488
BUN (mg/dL)	0.089	0.444
Serum creatinine (mg/dL)	0.124	0.285
Total protein (g/dL)	0.095	0.412
Serum albumin (g/dL)	0.144	0.214
ALP (IU/L)	0.057	0.623
AST (IU/L)	-0.043	0.715
ALT (IU/L)	0.008	0.946
Total bilirubin (mg/dL)	-0.056	0.633
Complements		

eDII: empirical dietary inflammatory index; AAV: ANCA-associated vasculitis; ANCA: antineutrophil cytoplasmic antibody; SF-36: Short-Form 36-Item Health Survey; PCS: physical component summary; MCS: mental component summary; BVAS: Birmingham vasculitis activity score; VDI: vasculitis damage index; ESR: erythrocyte sedimentation rate; CRP: C-reactive protein; WBC: while blood cell; BUN: blood urea nitrogen; ALP: alkaline phosphatase; AST: aspartate aminotransferase; ALT: alanine aminotransferase; C3: complement 3; C4: complement 4.

Variables	Correlation coefficient (r)	P-value
C3 (mg/dL)	0.095	0.417
C4 (mg/dL)	0.134	0.249

eDII: empirical dietary inflammatory index; AAV: ANCA-associated vasculitis; ANCA: antineutrophil cytoplasmic antibody; SF-36: Short-Form 36-Item Health Survey; PCS: physical component summary; MCS: mental component summary; BVAS: Birmingham vasculitis activity score; VDI: vasculitis damage index; ESR: erythrocyte sedimentation rate; CRP: C-reactive protein; WBC: while blood cell; BUN: blood urea nitrogen; ALP: alkaline phosphatase; AST: aspartate aminotransferase; ALT: alanine aminotransferase; C3: complement 3; C4: complement 4.

SF-36 MCS among the three groups

The low, moderate, and high eDII groups included 5 (6.0%), 40 (47.6%), and 39 (46.4%) patients, respectively. SF-36 MCS of patients with AAV among the low, moderate, and high eDII groups did not differ significantly (69.2, 70.1, and 56.7, respectively, P = 0.052) (Fig. 1A). However, since these median values were similar between the patients of the low and moderate eDII groups, the patients were then divided into two groups; the lower eDII group, including both the low and moderate eDII groups, and the higher eDII group including the high eDII group. There was a significant difference in the median SF-36 MCS between the lower and higher eDII groups (69.7 vs. 56.7, P = 0.016) (Fig. 1B).

Relative risk

In a previous study, the cut-off score of SF-36 MCS, which can predict the depressive status based on K-CESD-R ≥ 16, was 48.07, which was close to the upper limit of the lowest tertile value of 50.00 [14]. Therefore, although K-CESD-R ≥ 16 could not be applied, the depressive status could be anticipated from the lowest tertile of SF-36 MCS. Thus, we investigated whether the higher eDII group could predict the lowest tertile of SF-36 MCS. When patients with AAV were divided into two groups according to the upper limit of the lowest tertile of SF-36 MCS of 55.31, there were 28 patients in the lowest tertile of SF-36 MCS. Patients in the higher eDII group exhibited a significantly higher risk for the lowest tertile of SF-36 MCS than those in the lower eDII group (RR 3.000 95% confidence interval 1.168, 7.707) (Fig. 2).

Discussion

This study investigated whether the eDII is associated with the inflammatory burden or the depressive status in patients with AAV and obtained several interesting findings. First, the eDII scores inversely correlated with only SF-36 MCS with a statistically significant difference. Second, when the patients with AAV were divided into two groups according to the eDII scores, those in the higher eDII group exhibited significantly lower median SF-36 MCS than those in the lower eDII group. Third, patients in the higher eDII group exhibited a significantly higher risk for the lowest tertile of SF-36 MCS than those in the lower eDII group (RR 3.000). Therefore, we can conclude that the eDII scores can predict the current depressive status based on SF-36 MCS scores.

The depressive status should be defined based on K-CESD-R ≥ 16 [15]. However, at the start of this study, a correlation between the eDII scores and BVAS or the values of acute-phase reactants was expected; thus, we did not fill out the K-CESD-R form in this study. Nevertheless, we replaced the lowest tertile of SF-36 MCS with the cut-off of SF-36 MCS based on K-CESD-R ≥ 16 to determine the depressive status. This was done because the cut-off of SF-36 MCS, which can predict the depressive status based on K-CESD-R ≥ 16, was close to the upper limit of the lowest tertile value of 50.0 in a previous study [14]. In this study, the upper limit of the lowest SF-36 MCS was 55.31. If K-CESD-R had been used to assess the study participants, the cut-off of SF-36 MCS for the depressive status based on K-CESD-R would be close to 55.31, because the patients were selected from the same cohort as of the previous study. It is believed that the eDII scores are clinically significant in patients with AAV in the higher eDII group, who may be more susceptible to the depressive status based on the lowest tertile of SF-36 MCS than those in the lower eDII group.

There is a temporal difference between the eDII and SF-36 MCS questionnaires. SF-36 MCS assesses the mental health and emotional state over the past month, while the eDII scores assess the food intake over the past week [16, 17]. Given the time gap, this study investigated whether the eDII score directly predicted the lowest tertile of SF-36 and indirectly predicted the depressive status. As food intake patterns are more of habit than taste, they tend to persist over a relatively long period of time rather than change over a short period. Therefore, we can conclude that the results of this study are reliable. Moreover, the eDII score is more suitable for predicting SF-36 MCS with relatively small changes in the long term than BVAS or CRP levels with large changes in the short term.

Additionally, although the eDII score did not significantly correlate with the AAV-specific indices other than SF-36 MCS and acute-phase reactants, we compared their median values between the higher and lower eDII groups (Fig. 1B. Among the measures of SF-36 PCS, BVAS, VDI, ESR, and CRP, patients in the higher eDII score group exhibited a higher median BVAS than those in the lower group (5.0 vs. 4.0, P = 0.099) (**Supplementary Fig. 1**). However, this difference was not statistically significant. We conclude that the eDII score may not be useful in estimating the cross-sectional inflammatory burden based on BVAS or acute-phase reactants.

The strength of this study is that for the first time, the inverse correlation between the conveniently revised eDII scores based on the DII and the cross-sectional SF-36 MCS score was revealed. However, this study also has several limitations that should be considered. The number of patients with AAV participating in this study was not adequate to generalise the results to all Korean patients with AAV. Furthermore, this study was designed to compare both the eDII scores and the AAV-specific indices at two different time points. However, the follow-up eDII score could not be completed, because a significant number of patients did not respond to the eDII and SF-36 questionnaires due to the SARS-CoV-2 pandemic. Since this study was conducted during the pandemic, it is unclear whether the study accurately reflected the situation before or after the pandemic. Therefore, if future studies with a large number of patients with AAV that involve completing the DII and SF-36 MCS questionnaires at two or more different times after the pandemic are warranted, they could provide dynamic and more reliable

information regarding the clinical implications of the eDII for managing patients with AAV in actual clinical practice.

Conclusions

We demonstrated for the first time that the eDII scores inversely correlated with the cross-sectional score of SF-36 MCS in patients with AAV. Given that the lowest tertile of SF-36 MCS and K-CESD-R ≥ 16 were similar in a previous study [14], the eDII score may be useful in predicting the depressive disorder without utilising K-CESD-R ≥ 16 in patients with AAV.

Abbreviations

AAV: ANCA-associated vasculitis; ANCA: antineutrophil cytoplasmic antibody; BVAS: Birmingham vasculitis activity score; C: cytoplasmic; CRP: C-reactive protein; DII: dietary inflammatory index; eDII: empirical dietary inflammatory index; EGPA: eosinophilic granulomatosis with polyangiitis; ESR: erythrocyte sedimentation rate; GPA: granulomatosis with polyangiitis; K-CESD-R: Korean version of centre for epidemiologic studies depression scale-revised; MCS: mental component summary; MPA: microscopic polyangiitis; MPO: Myeloperoxidase; P: perinuclear; PCS: physical component summary; PR3: proteinase 3; RR: relative risk; SF-36: short-form 36-item Health Survey; VDI: vasculitis damage index.

Declarations

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Not applicable.

Authors' contributions

JL, JY and SL designed the study. JL, JY, JW, JP and SA obtained funding and managed the study. JL, and SL wrote the first draft of the manuscript. JL, JY, JP and SL collected and managed data. JL, JW and SL analysed data. JL, JY, JW, JP, SA, and SL reviewed literature interpreted data, revised manuscript. JS and YP reviewed the draft manuscript and validate data. All authors read and approved the final manuscript.

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Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Ethics approval and consent to participate

This study was approved by the Institutional Review Board of Severance Hospital (4-2016-0901) and conducted according to the Declaration of Helsinki. The patients' written informed consent was obtained from all patients.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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Figures

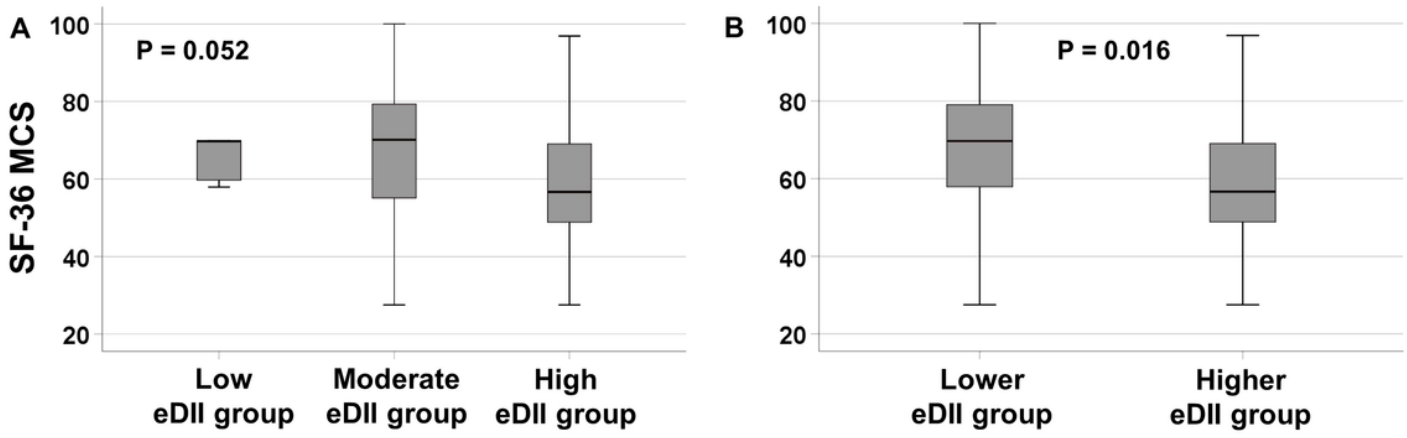

Figure 1

(A) SF-36 scores among the low, moderate, and high eDII groups. (B) SF-36 scores between the lower and higher eDII groups. SF-36: Short-Form 36-Item Health Survey; eDII: empirical dietary inflammatory index.

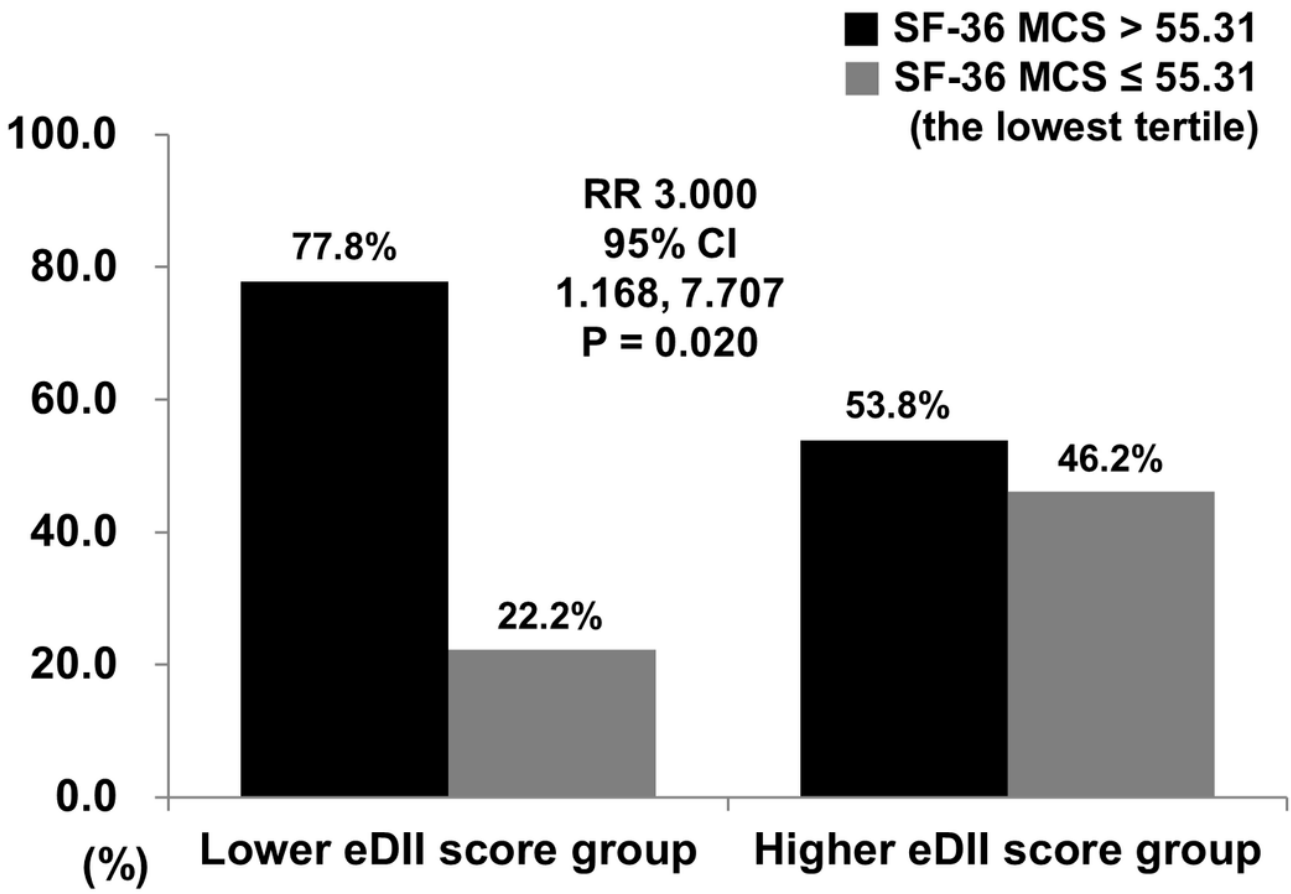

Figure 2

Relative risk of the higher eDII group for the lowest tertile of SF-36 MCS. eDII: empirical dietary inflammatory index; SF-36: Short-Form 36-Item Health Survey; MCS: mental component summary.

Supplementary Files

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