

The Association between the Dietary Inflammatory Index (DII) and Body Composition in Elite and Sub-Elite Soccer Players and Referees: A Cross-Sectional Study

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Abstract

Background: For optimal performance, athletes from all sport disciplines need to consume a high-quality diet. The Dietary Inflammatory Index (DII) is a tool that can estimate diet quality and has been shown to be associated with body composition. The aims of this study were, first, to assess the DII score of diets consumed by soccer players and referees, and second to examine its association with body composition in these two groups.

Methods: A cross-sectional study was conducted on 199 male and female soccer players and referees. Dietary intakes were recorded using a validated food frequency questionnaire, dietary information was then entered into Nutritionist IV software and DII score was calculated. All anthropometric indices including BMI, PBF, PMM, WHR, WHtR, and BMC were assessed either through manual measurements or using bioelectrical impedance analysis. Physical activity was also measured using short form of international physical activity questionnaire. Multiple linear regression was used to assess associations between DII and each anthropometric index, with all analyses performed using SPSS version 25.0.

Results: The mean DII score was -0.01 . After adjustment for age, sex, and physical activity, DII was not significantly associated with BMI ($\beta = -0.56-0.05$; 95% CI: $-1.21-0.77$), PBF ($\beta = -0.53-0.79$; 95% CI: $-2.59-2.22$), PMM ($\beta = -0.79-0.53$; 95% CI: $-2.22-2.59$), WHR ($\beta = -0.004-0.007$; 95% CI: $-0.13-0.21$), WHtR ($\beta = -0.003-0.005$; 95% CI: $-0.13-0.01$), or BMC ($\beta = -0.14-0.04$; 95% CI: $-0.34-0.16$) across the six athlete groups (all $P = 0.07-0.97$).

Conclusions: The mean DII score indicated that soccer players and referees generally consumed a neutral to mildly anti-inflammatory diet. However, after adjustment for potential confounders, DII was not significantly associated with any body composition parameter. These findings suggest that, within this population, DII may not be an independent determinant of body composition.

Keywords: Dietary inflammatory index, Body composition, Soccer players, Soccer referee

Introduction

Soccer is the most popular sport globally, with more than 200 million followers worldwide [1,2]. Whilst the soccer players play the most influential role in this sport [3,4], the soccer referees

have an important role in the modern soccer [5–8]. Time and motion analysis has revealed that referees, on average, cover around 10–12 km during a match, with 4–18% of this match-distance covered at speeds faster than 13–15 km/h [9], which is pretty similar to what is observed in midfield soccer players

[4,10]. Optimal athletic performance, among many other factors, depends on body composition which may have an effect on athlete's strength, agility, and appearance [11]. To sustain and improve athletic performance, both soccer players and referees are advised to consume a high-quality diet to help maintain an excellent body composition. Therefore, a healthy diet with optimal calories, macro- and micronutrients is crucial for the optimal performance of soccer players and referees during training and matches [12–15].

Diet quality can be assessed using a variety of dietary indices that have been developed to reflect adherence to established nutritional guidelines or dietary patterns. Commonly used indices include the Healthy Eating Index (HEI) [16], Mediterranean Diet Score (MDS) [17], Diet Quality Index-International (DQI-I) [18], and the Alternative Healthy Eating Index (AHEI) [19]. These tools have been widely applied in nutritional epidemiology and public health research and are supported by leading organizations such as the United States Department of Agriculture (USDA). DII is another tool for diet quality assessment that categorizes an individual's diet on a continuum from maximally pro-inflammatory to maximally anti-inflammatory [20]. Several studies have investigated the association of DII and body composition among healthy non-athletic adults [21–26], but to the best of our knowledge, no single study has investigated the association of DII with body composition among male and female soccer players and referees before. The different genetics of Iranians, traditional Iranian dishes, variations in cooking methods, as well as the higher levels of physical activity and nutritional knowledge in athletic compared to non-athletic populations [27–29] are among the key determinants that may influence body composition, help distinguish between athletic and non-athletic individuals, and highlight the novelty of the present study. Thus, the aims of this study were, first, to assess the DII score of diets consumed by soccer players and referees, and second to examine its association with body composition in these two groups.

Materials and Methods

Study population and design

This was a cross-sectional study conducted on 199 elite (11 male and 23 female) and sub-elite (12 male and 24 female) soccer players and referees (90 male and 39 female) in Iran, during the early stage of the 2019–2020 competitive season. Participants' demographic information (age, gender and education), physical activity, medical history, anthropometric measures, and dietary intakes were assessed via a face-to-face interview.

Convenience sampling was used for this study, and all soccer players and referees who agreed to participate in the present study were included. The sample size was estimated

a priori based on the primary analysis, which was a multiple linear regression examining the association between the DII and Body Mass Index (BMI), while adjusting for age, sex, and physical activity. BMI was prespecified as the primary outcome, whereas Percent Body Fat (PBF), Percent Puscle Pass (PMM), Waist-to-Hip Ratio (WHR), Waist-to-Height Ratio (WHtR), and Bone Mineral Content (BMC) were considered secondary outcomes. The incremental contribution of DII to the explained variance in BMI was evaluated using the effect size f^2 , calculated as $f^2 = (R^2_{\text{full}} - R^2_{\text{reduced}}) / (1 - R^2_{\text{full}})$, where the full model included DII, age, sex, and physical activity, and the reduced model included only the covariates. A previous study conducted among professional male football players reported a moderate positive correlation between DII and abdominal adiposity ($r=0.476$); however, the study included only 21 participants, and the reported association was based on a bivariate analysis [30]. Therefore, directly applying the corresponding effect size to the present multivariable analysis could result in an overly optimistic estimate. To provide a conservative sample size estimation and account for the expected attenuation of the association after adjustment for potential covariates, an effect size of $f^2=0.05$ was assumed, representing a small-to-moderate incremental effect. With a two-sided significance level of 0.05, 80% statistical power, four predictors in the full regression model, and one tested predictor (DII), the required sample size was estimated to be 159 participants using G*Power. As 199 eligible participants agreed to participate in the study, all available participants were included in the analysis, providing a sample size greater than the minimum required sample and thereby allowing for potential exclusions due to incomplete or missing data. Data collection, including demographic information, anthropometric measurements, dietary intake, and physical activity was conducted at the Medical Committee of the Islamic Republic of Iran Soccer Federation.

This study was conducted according to the guidelines laid down in the Declaration of Helsinki [31] and all procedures involving human subjects were approved by the [Tehran University of Medical Sciences Ethics Committee; (Ethic number: IR.TUMS.VCR.REC.1398.729)]. All subjects were given verbal and written communication about the study before signing an informed consent form.

Assessment of dietary intakes

Dietary intakes were collected using a 147-item semi-quantitative Food Frequency Questionnaire (FFQ) which was validated for Tehran Lipid and Glucose Study (TLGS). This questionnaire examines food intakes of the past 12 months, and its validity and reliability have previously been confirmed [32]. Dietary intakes were then entered into Nutritionist IV software modified for Iranian foods to estimate average energy, macro- and micro-nutrients.

DII calculation

The DII consists of 45 dietary components and each one scores according to its potential to whether increase (inflammatory or +1), decrease (anti-inflammatory or -1) or has no effect (0) on six inflammatory biomarkers, including Interleukins (IL-1 β , IL-4, IL-6, IL-10), Tumor necrosis factor-alpha (TNF- α) and C-Reactive Protein (CRP).

In order to calculate DII score for each subject we followed 6 steps below:

A. The amount of food items consumed by an athlete is deducted from the global intake which is listed in **Supplemental Table 1**

B. The value obtained was divided by the SD listed in **Supplemental Table 1**

C. That value was converted to percentiles

D. Multiplied by 2

E. Subtracted from 1

F. And finally multiplied it to overall inflammatory effect score provided in **Supplemental Table 1**.

An individual's score can vary from +7.98 (completely inflammatory) to -8.87 (completely anti-inflammatory) points and the median score is +0.23 [20].

Since the FFQ used in the present study did not cover all 45 components of the original DII, the DII score was calculated based on 32 available dietary components, while 13 components (including alcohol, eugenol, ginger, saffron, turmeric, flavan 3-ol, flavones, flavonols, flavonones, anthocyanidins, isoflavones, thyme/oregano, and rosemary) that were not assessed by the FFQ were excluded from the calculation.

Assessment of body composition

Body composition was measured using the InBody 570 device (InBody Co., Ltd. in Seoul, Korea) to quantify lean mass, fat mass, PBF, PMM and BMC. Calibration took place as per manufacturer guidelines. Athletes were advised not to consume caffeinated beverages at least 4 hours before, and to drink at least 2–4 glasses of water 2 hours prior to scanning. Measurements were conducted after an overnight fast and rest, without exercising on the morning of the scan. Participants were also required to empty their bladders before each scan, and to wear minimal clothing. Scans were automatically analyzed using the software. Body mass was measured with subjects in light clothing, upshot, using a digital scale (Seca 808, Germany) to the nearest 0.1 kg. Height was assessed using a wall-mounted stadiometer (Seca, Germany) to the nearest 0.1 cm, and BMI was calculated by dividing weight

(kg) by height (m) squared. Waist and Hip Circumferences (WC and HC) were measured at the midpoint of the lowest rib and iliac crest at the end of expiration, and at the widest point over the buttocks respectively using a non-elastic measuring tape to the nearest 0.1 cm. WHR and WHtR were then obtained by dividing the WC by the HC and height respectively.

Assessment of physical activity

Information about physical activity was collected using a 7-item (short form) International Physical Activity Questionnaire (IPAQ), the validity and reliability of this questionnaire have previously been described and confirmed [33]. A shortened form of this questionnaire was used, so that athletes would have less difficulty remembering and would cooperate better. The questionnaire asks participants about all types of physical activity that were done in the past 7 days. Individuals were then divided into 3 groups in terms of physical activity:

1. Low physical activity: This group does not meet any of the criteria for subsequent groups

2. Average: Having any type of physical activity (light, moderate or heavy) for 5 days or more in a week to meet 600MET/minute/week.

3. High physical activity: Having any type of physical activity (light, moderate or heavy) for 7 days in a week to meet 3000MET/minute/week.

Confounder adjustment

The covariates included in the regression analyses (age, sex, and physical activity) were determined a priori based on previous research indicating their potential relevance to the outcomes examined [34]. We also assessed the available data for other plausible confounding factors (including total energy intake and BMI) and found no additional variables that warranted inclusion beyond those identified from the literature. Accordingly, the final models reflected a combination of theory- and evidence-based selection and empirical assessment of the dataset, rather than relying exclusively on data-driven variable selection. All pre-specified covariates were entered concurrently into the regression models to account for their potential confounding effects.

Statistical methods

The Statistical Package for Social Science (SPSS) version 25.0 (Chicago, IL, USA) for windows was used for all statistical analyses and statistical significance was set at $P < 0.05$. All variables were tested for normality via the Shapiro–Wilk statistic and visual assessment of histograms, and appropriate statistical tests were subsequently conducted. Data are presented as percentages, means, and standard deviations.

Descriptive statistics (Frequencies, cross tabulation and Chi-square value) were used to describe the main features of the data. Participants' general characteristics were compared across tertiles of DII using analysis of variances (ANOVA) for continuous variables. Pearson's correlation coefficient was used to discern the correlation between DII and different body composition parameters. Prior to conducting the regression analyses, the assumptions of linear regression were systematically assessed. The normality of the residuals was evaluated using histograms, normal probability (Q–Q) plots, and the Shapiro–Wilk test with the residuals showing an approximately normal distribution ($P=0.12$ for the Shapiro–Wilk test). Linearity was assessed by examining the relationship between the predicted values and standardized residuals, as well as partial regression plots for the primary predictor, and no evidence of substantial non-linear patterns was observed. Homoscedasticity was evaluated using scatterplots of standardized residuals against standardized predicted values, which showed a relatively constant spread of residuals across the range of predicted values, indicating no apparent heteroscedasticity. The independence of residuals was assessed using the Durbin–Watson statistic, with no evidence of problematic residual autocorrelation. Multicollinearity among DII and the covariates (age, sex, and

physical activity) was assessed using variance inflation factor (VIF) and tolerance statistics. All VIF values were below 5 and tolerance values exceeded 0.20, indicating no evidence of problematic multicollinearity. Multivariate regression models were created to identify associations between DII and body composition parameters in the crude and the final model which was adjusted for age, sex, and physical activity as potential confounding variables.

Results

Participants' general characteristics across tertiles of DII are shown in **Table 1**. A total of 199 athletes participated in this study of which 113 (56.8%) were males and 86 (43.2%) were females. Mean age of the participants was 29.34 ± 8.46 years, of that 36 (18.1%) were under 18 and 163 (81.9%) were over 18 years of age. Mean physical activity was 3003.75 ± 1834.97 MET/min/week, and, according to this number 144 (72.4%) followed a moderate physical activity and 55 (27.6%) followed a high physical activity lifestyle. No significant differences were observed in participants' general characteristics ($P>0.05$), indicating that our study population was almost homogeneous.

Table 1. General characteristics of participants across tertiles of dietary inflammatory index (DII).

	Dietary Inflammatory Index								η ² / Cramér's V	P-value
	Tertile1 (N=66)		Tertile2 (N=67)		Tertile3 (N=66)		Total (N=199)			
	Mean	SD	Mean	SD	Mean	SD	Mean	SD		
Range	<-1.2		-1.2 to 1.2		>1.2					
Mean score ^a	-2.59	1.05	0.00	0.79	2.56	1.01	-0.01	2.31	0.82	<0.001
Age (year) ^{a/b}	29.74	7.77	30.01	9.25	28.26	8.29	29.34	8.46	0.008	0.43
< 18 years	11 (16.7%)		12 (17.9%)		13 (19.7%)		36 (18.1%)		0.03	
≥ 18 years	55 (83.3%)		55 (82.1%)		53 (80.3%)		163 (81.9%)			
Gender ^b									0.11	0.25
Male	32 (48.5%)		41 (61.2%)		40 (60.6%)		113 (56.8%)			
Female	34 (51.5%)		26 (38.8%)		26 (39.4%)		86 (43.2%)			
Post ^b									0.06	0.65
Soccer players	21 (31.8%)		23 (34.3%)		26 (39.4%)		70 (35.2%)			
Soccer referees	45 (68.2%)		44 (65.7%)		40 (60.6%)		129 (64.8%)			
Physical activity ^b									0.01	0.98
Moderate	48 (72.7%)		48 (71.6%)		48 (72.7%)		144 (72.4%)			
High	18 (27.3%)		19 (28.4%)		18 (27.3%)		55 (27.6%)			
Physical activity ^a									0.02	0.07
MET/Min/Week	3020.08	1804.68	2635.80	1356.49	3360.95	2205.02	3003.75	1834.97		
Height (cm) ^a	172.58	8.91	173.15	8.54	172.12	7.84	172.62	8.41	0.002	0.78
Weight (kg) ^a	66.26	10.77	68.44	10.16	67.27	9.93	67.33	9.69	0.008	0.43

	Dietary Inflammatory Index								η^2 / Cramér's V	P-value
	Tertile1 (N=66)		Tertile2 (N=67)		Tertile3 (N=66)		Total (N=199)			
	Mean	SD	Mean	SD	Mean	SD	Mean	SD		
BMI (kg/m ²) ^a	22.42	2.22	22.69	2.10	22.30	1.80	22.47	2.04	0.006	0.54
BFM (kg) ^a	13.18	3.78	12.61	3.34	12.28	4.15	12.69	3.77	0.009	0.38
PBF (%) ^a	20.21	6.15	18.59	4.62	18.33	6.19	19.04	5.73	0.02	0.12
FFM (Kg) ^a	53.08	10.72	55.83	9.58	54.99	8.00	54.64	9.52	0.01	0.23
PMM (%) ^a	79.78	6.15	81.40	4.62	81.66	6.19	80.95	5.73	0.02	0.12
WHR ^a	0.82	0.03	0.81	0.03	0.81	0.03	0.81	0.03	0.02	0.08
WHtR ^a	0.45	0.03	0.45	0.03	0.45	0.03	0.45	0.03	0.005	0.67
BMC (kg) ^a	3.09	0.61	3.22	0.52	3.19	0.43	3.17	0.53	0.01	0.32

BMI: Body Mass Index; BFM: Body Fat Mass; PBF: Percent Body Fat; FFM: Fat Free Mass; PMM: Percent Muscle Mass; WHR: Waist to Hip Ratio; WHtR: Waist to Height Ratio; BMC: Bone Mineral Content

η^2 (eta squared), representing the proportion of variance in continuous variables explained by differences between DII tertiles; Cramér's V, a measure of the strength of association between categorical variables and DII tertiles.

Normality of continuous variables was assessed using the Shapiro–Wilk test and visual methods (histograms), and parametric tests were applied when appropriate.

a Values are expressed as mean $\pm$ SD, by using one-way ANOVA

b Values are reported as total and percentage, by using cross-tabulation and Chi-square test

P-value is considered significant at <0.05 .

Scores for each component and the final score for DII are shown in **Table 2**. A Holm–Bonferroni correction was applied for multiple comparisons. Mean DII was -0.01 ± 2.31 , and a significant difference was found between tertiles of DII ($P < 0.001$). Furthermore, all individual scores were significantly different across the tertiles of DII except for trans-fat score ($P = 0.145$), which suggests all our subjects were consuming a zero trans-fat diet. Energy, carbohydrates, protein, total fat, Mono-Unsaturated Fatty Acids (MUFAs), Poly Unsaturated Fatty Acids (PUFAs), Saturated Fatty

Acids (SFAs), cholesterol, omega-3 fatty acids, omega-6 fatty acids, fiber, beta-carotene, vitamins B1, B2, B3, B6, B9, B12, A, C, E, Fe, Mg, Se and Zn were significantly different across all tertiles of DII. Intakes of garlic, onion and pepper were significantly different between tertiles 1 and 2 and tertiles 1 and 3. Caffeine and tea intakes were significantly different between tertiles 1 and 3 and vitamin D intakes were significantly different between tertiles 1 and 3 and tertiles 2 and 3 according to Tukey's test, with further details provided in **Supplemental Table 2**.

Table 2. Comparison of components of Dietary Inflammatory Index score across tertiles of DII.

Dietary Inflammatory Index components	Dietary Inflammatory Index								P-value
	Tertile 1 (n=66)		Tertile 2 (n=67)		Tertile 3 (n=66)		Total (N=199)		
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
Vitamin B12 (mcg)	0.34	0.53	0.00	0.58	-0.03	0.04	0.00	0.06	<0.001
Vitamin B6 (mg)	-0.20	0.11	-0.01	0.13	0.20	0.10	-0.00	0.20	<0.001
Beta-carotene (mcg)	-0.28	0.22	-0.00	0.27	0.28	0.21	-0.00	0.33	<0.001
Caffeine (g)	-0.02	0.06	-0.00	0.06	0.02	0.05	-0.00	0.06	0.001
Carbohydrate (g)	0.05	0.03	-0.00	0.03	-0.05	0.03	0.00	0.05	<0.001
Cholesterol (mg)	0.03	0.05	0.00	0.06	-0.03	0.04	0.00	0.06	<0.001
Energy (kcal)	0.09	0.05	0.00	0.07	-0.09	0.06	0.00	0.10	<0.001

Dietary Inflammatory Index components	Dietary Inflammatory Index								P-value
	Tertile 1 (n=66)		Tertile 2 (n=67)		Tertile 3 (n=66)		Total (N=199)		
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
Total Fat (g)	0.13	0.12	0.01	0.14	-0.11	0.12	0.00	0.16	<0.001
Total Fiber (g)	-0.36	0.22	0.00	0.25	0.36	0.20	0.00	0.37	<0.001
Vitamin B9 (mcg)	-0.10	0.05	0.00	0.07	0.10	0.05	-0.00	0.10	<0.001
Garlic (g)	-0.08	0.19	0.01	0.25	0.03	0.22	-0.00	0.23	0.007
Fe (mg)	0.01	0.01	-0.00	0.01	-0.01	0.01	0.00	0.01	<0.001
Mg (mg)	-0.28	0.14	0.00	0.18	0.26	0.13	-0.00	0.27	<0.001
MUFA (g)	-0.00	0.00	-0.00	0.00	0.00	0.00	-0.00	0.00	<0.001
Vitamin B3 (mg)	-0.13	0.09	0.00	0.10	0.12	0.08	-0.00	0.13	<0.001
Omega-3 (g)	-0.16	0.19	-0.00	0.24	0.14	0.21	-0.00	0.25	<0.001
Omega-6 (g)	-0.07	0.06	0.00	0.07	0.06	0.07	-0.00	0.09	<0.001
Onion (g)	-0.07	0.15	0.00	0.17	0.06	0.16	-0.00	0.17	<0.001
Protein(g)	0.01	0.00	0.00	0.00	-0.01	0.00	0.00	0.01	<0.001
PUFA (g)	-0.15	0.13	0.00	0.15	0.13	0.15	-0.00	0.19	<0.001
Vitamin B2 (mg)	-0.03	0.02	-0.00	0.02	0.03	0.02	-0.00	0.03	<0.001
Saturated Fat (g)	0.13	0.17	0.01	0.18	-0.11	0.17	0.01	0.20	<0.001
Se (mcg)	-0.09	0.07	0.00	0.09	0.08	0.07	-0.00	0.10	<0.001
Vitamin B1 (mg)	-0.05	0.03	0.00	0.04	0.04	0.04	-0.00	0.05	<0.001
Trans Fat (g)	0.02	0.09	0.01	0.10	-0.01	0.12	0.00	0.10	0.145
Vitamin A (RE)	-0.20	0.16	-0.01	0.18	0.20	0.12	-0.00	0.22	<0.001
Vitamin C (mg)	-0.20	0.16	-0.01	0.18	0.23	0.12	0.00	0.24	<0.001
Vitamin D (mcg)	-0.09	0.24	-0.01	0.25	0.13	0.21	0.00	0.25	<0.001
Vitamin E (mg)	-0.20	0.17	-0.03	0.17	0.21	0.14	-0.00	0.23	<0.001
Zn (mg)	-0.17	0.10	0.00	0.12	0.16	0.10	-0.00	0.17	<0.001
Tea (g)	-0.10	0.29	0.00	0.30	0.09	0.28	-0.00	0.30	0.001
Pepper (g)	-0.03	0.06	0.00	0.07	0.01	0.07	-0.00	0.07	<0.001
Dietary Inflammatory Index Score	-2.59	1.05	0.00	0.79	2.56	1.01	-0.01	2.31	<0.001

MUFA: Mono Unsaturated Fatty Acids; PUFA: Poly Unsaturated Fatty Acids

A Holm–Bonferroni correction was applied for multiple comparisons

Values are expressed as Mean ± SD. ANOVA analysis is used to compare means between tertiles of DII.

P-value is considered significant at <0.05.

The correlations between DII and body composition parameters according to the crude model are shown in **Table 3**. BMI in<18 male soccer players (P=0.03), and PBF (P=0.04), PMM (P=0.04), WHR (P=0.04), and WHtR (P=0.03) in≥18 male soccer players were showed to be significantly associated with DII. P-values obtained from the regression analyses were adjusted for multiple testing using the Benjamini–Hochberg false discovery rate (FDR) procedure.

The associations between DII and body composition parameters were then assessed after adjusting for age, sex and physical activity, as potential covariates which is shown in **Table 4**. The significant associations seen in the crude model were completely attenuated in the adjusted model, suggesting that despite the anti-inflammatory nature of athletes' diets, there is no significant association between DII and various body composition parameters (P≥0.05).

Table 3. The correlation between dietary inflammatory index (DII) score and different body composition parameters among different categories of athletes in crude model.

Categories of Athletes	BMI	PBF	PMM	WHR	WHtR	BMC
	r^a (P) ^b	r^a (P) ^b	r^a (P) ^b	r^a (P) ^b	r^a (P) ^b	r^a (P) ^b
	[95%CI]	[95%CI]	[95%CI]	[95%CI]	[95%CI]	[95%CI]
<18 male soccer players (N=12)	-0.60 (0.03)* [-1.39 to -0.04]	0.30 (0.33) [-3.22 to 1.19]	0.30 (0.33) [-1.19 to 3.22]	0.005 (0.98) [-0.01 to 0.01]	0.33 (0.28) [-0.01 to 0.006]	-0.41 (0.18) [-0.31 to 0.06]
≥18 male soccer players (N=11)	0.12 (0.71) [-0.61 to 0.85]	0.61 (0.04)* [0.03 to 2.37]	-0.61 (0.04)* [-2.37 to -0.03]	0.62 (0.04)* [0.001 to 0.02]	0.62 (0.03)* [0.001 to 0.01]	0.20 (0.54) [-0.27 to 0.15]
<18 female soccer players (N=24)	0.09 (0.67) [-0.31 to 0.48]	-0.07 (0.72) [-1.14 to 0.81]	0.07 (0.72) [-0.81 to 1.14]	-0.07 (0.71) [-0.01 to 0.003]	0.03 (0.88) [-0.007 to 0.005]	0.243 (0.12) [-0.08 to 0.09]
≥18 female soccer players (N=23)	-0.23 (0.29) [-0.47 to 0.14]	-0.35 (0.09) [-1.26 to 0.11]	0.35 (0.09) [-0.11 to 1.26]	0.39 (0.06) [-0.01 to 0.001]	0.10 (0.64) [-0.007 to 0.005]	0.40 (0.05) [-0.001 to 0.08]
Male soccer referees (N=90)	0.10 (0.34) [-0.07 to 0.20]	0.05 (0.58) [-0.23 to 0.42]	0.05 (0.58) [-0.42 to 0.23]	0.08 (0.43) [-0.004 to 0.002]	0.07 (0.49) [-0.002 to 0.003]	0.09 (0.37) [-0.04 to 0.01]
Female soccer referees (N=39)	-0.05 (0.74) [-0.41 to 0.29]	-0.10 (0.53) [-1.04 to 0.54]	0.10 (0.53) [-0.54 to 1.04]	0.07 (0.64) [-0.004 to 0.006]	-0.02 (0.87) [-0.006 to 0.005]	0.24 (0.13) [-0.01 to 0.07]

BMI: Body Mass Index; BMC: Bone Mineral Content; CI: Confidence Intervals; PBF: Percent Body Fat; PMM: Percent Muscle Mass; WHR: Waist to Hip Ratio; WHtR: Waist to Height Ratio.

^a r^a : Pearson correlation coefficient

^b P*: significant value.

P-values were adjusted for multiple testing using the Benjamini-Hochberg false discovery rate procedure.

Correlation is significant at the 0.05 level (2-tailed)

Table 4. The association between Dietary Inflammatory Index (DII) score and body composition among different categories of athletes in final model.

Categories of Athletes	Body composition parameters	Dietary Inflammatory Index					
		Unstandardized β coefficient	SE	95% CI	Standardized β coefficient	Adjusted R ²	P-value
<18 male soccer players (N=12)	BMI (kg/m²)	-0.56	0.28	-1.21 to 0.08	-0.47	0.42	0.08
	PBF (%)	-0.48	0.93	-2.59 to 1.62	-0.14	0.20	0.61
	PMM (%)	0.48	0.93	-1.62 to 2.59	0.14	0.20	0.61
	WHR	0.003	0.007	-0.13 to 0.20	0.14	0.20	0.64
	WHtR	-0.003	0.005	-0.13 to 0.008	-0.14	0.38	0.58
	BMC (kg)	-0.14	0.09	-0.34 to 0.06	-0.47	0.03	0.16
≥18 male soccer players (N=11)	BMI (kg/m²)	-0.13	0.38	-1.03 to 0.77	-0.13	-0.13	0.74
	PBF (%)	0.79	0.60	-0.64 to 2.22	0.40	0.29	0.23
	PMM (%)	-0.79	0.60	-2.22 to 0.64	-0.40	0.29	0.23
	WHR	0.007	0.006	-0.006 to 0.21	0.36	0.40	0.23
	WHtR	0.005	0.004	-0.004 to 0.01	0.32	0.54	0.23
	BMC (kg)	-0.08	0.10	-0.34 to 0.16	-0.30	-0.05	0.44

Categories of Athletes	Body composition parameters	Dietary Inflammatory Index					
		Unstandardized β coefficient	SE	95% CI	Standardized β coefficient	Adjusted R^2	P-value
<18 female soccer players (N=24)	BMI (kg/m ²)	0.05	0.22	-0.40 to 0.51	0.06	0.10	0.79
	PBF (%)	-0.17	0.58	-1.39 to 1.03	-0.08	-0.05	0.76
	PMM (%)	0.17	0.58	-1.03 to 1.39	0.08	-0.05	0.76
	WHR	-0.004	0.006	-0.01 to 0.008	-0.19	-0.05	0.47
	WHtR	-0.001	0.004	-0.009 to 0.006	-0.09	-0.05	0.71
	BMC (kg)	0.01	0.05	-0.09 to 0.12	0.09	-0.009	0.71
≥18 female soccer players (N=23)	BMI (kg/m ²)	-0.16	0.13	-0.45 to 0.12	-0.23	0.18	0.24
	PBF (%)	-0.53	0.30	-1.17 to 0.11	-0.32	0.23	0.10
	PMM (%)	0.53	0.30	-0.11 to 1.17	0.32	0.23	0.10
	WHR	-0.004	0.002	-0.009 to 0.001	-0.34	0.12	0.10
	WHtR	-0.001	0.003	-0.007 to 0.005	-0.05	0.08	0.77
	BMC (kg)	0.04	0.02	-0.005 to 0.08	0.39	0.04	0.07
Male soccer referees (N=90)	BMI (kg/m ²)	0.04	0.06	-0.09 to 0.17	0.06	0.09	0.55
	PBF (%)	0.006	0.15	-0.30 to 0.31	0.004	0.12	0.97
	PMM (%)	-0.006	0.15	-0.31 to 0.30	-0.004	0.12	0.97
	WHR	-0.002	0.001	-0.004 to 0.001	-0.11	0.06	0.27
	WHtR	0.000	0.001	-0.002 to 0.003	0.30	0.05	0.77
	BMC (kg)	-0.01	0.01	-0.04 to 0.01	-0.09	-0.18	0.38
Female soccer referees (N=39)	BMI (kg/m ²)	-0.05	0.16	-0.37 to 0.27	-0.04	0.14	0.74
	PBF (%)	-0.22	0.33	-0.91 to 0.45	-0.09	0.25	0.50
	PMM (%)	0.22	0.33	-0.45 to 0.91	0.09	0.25	0.50
	WHR	0.001	0.002	-0.003 to 0.006	0.08	0.23	0.53
	WHtR	0.000	0.002	-0.005 to 0.005	-0.01	0.21	0.90
	BMC (kg)	0.03	0.02	-0.01 to 0.07	0.23	0.06	0.15

BMC: Bone Mineral Content; BMI: Body Mass Index; CI: Confidence Interval; PBF: Percent Body Fat; PMM: Percent Muscle Mass; SE: Standard Error; WHR: Waist to Hip Ratio; WHtR: Waist to Height Ratio

A multiple linear regression model was created with adjustment for age, sex and physical activity level.

P-value is considered significant at <0.05.

Discussion

The DII and its association with different body composition parameters has not previously been investigated in elite and sub-elite soccer players and referees, therefore in the present study we tried first, to calculate the DII score of diets consumed by elite and sub-elite soccer players and referees, and then to investigate its association with various body composition parameters in these two groups. The mean DII score was -0.01 ± 2.31 among soccer players and referees, indicating that our athletes were consuming a neutral to mildly anti-inflammatory diet during the past 12 months. Although several significant associations were observed

between DII and anthropometric indices in the crude model, these associations were attenuated and no longer statistically significant after adjustment for the potential confounding variables of age, sex, and physical activity. This finding suggests that the associations observed in the crude models may have been partly influenced by differences in these covariates among participants. Age, sex, and physical activity may be related to both dietary inflammatory potential and anthropometric characteristics and may therefore contribute to the observed crude associations. After accounting for these potential confounders, there was insufficient evidence of an independent association between DII and the anthropometric indices examined. Nevertheless, given the cross-sectional

nature of the study, these findings should be interpreted cautiously, and the possibility of residual confounding cannot be completely excluded. This finding is noteworthy because the majority of previous evidence linking a more pro-inflammatory dietary pattern with adiposity has been derived from non-athletic or metabolically at-risk populations, whereas evidence in athletes remains limited and inconsistent.

Previous studies on non-athletic populations have found significant association between DII and body composition parameters, with higher DII scores associated with overweight and obesity (21–23, 25, 26). Diets with higher inflammatory loads indicated to be significantly associated with increased risk of weight regain after a weight loss program and remained significant after adjusting for physical activity ($P=0.03$), in this study participants regained approximately half of their lost weight following a pro-inflammatory diet [22]. Results of another study indicated that there was a significant association between DII score and serum leptin concentrations [26]. Another study revealed that there is a significant association between DII and BMI, WC and WHR [21]. Results of another study which was conducted on 599 young adults, found that weight and fat free mass were significantly associated with DII even after adjusting for physical activity [24]. A 2017 cohort study in Spain also found that a pro-inflammatory diet was significantly associated with higher annual weight gain and higher risk of developing new-onset overweight or obesity [23]. A meta-analysis that was conducted in 2018 also found that adherence to a diet scoring high in DII is associated with increased BMI and the risk of obesity [25].

Although the precise mechanisms initiating obesity-associated inflammation are not yet fully understood, expanding and dysfunctional adipose tissue is recognized as an important source and regulator of chronic low-grade inflammation through the release of pro-inflammatory cytokines and adipokines [35,36]. Importantly, the relationship between adiposity and inflammation may be bidirectional: a pro-inflammatory dietary pattern may contribute to the development or maintenance of excess adiposity, while nutrient excess and the consumption of certain foods or nutrients may promote inflammatory responses, potentially creating a self-perpetuating cycle of adiposity and inflammation [37]. The potential mechanisms underlying this association are thought to be due to the activation of pathogen-associated molecular patterns, such as the Toll-like receptors and Nod-like receptors, which induce the activation of inflammatory markers in several tissues, including adipose tissue [38]. Additionally, dietary patterns (e.g. high fat/low fiber or low fat/high fiber diet) and some specific nutrients may have effects on the gut microbiota, which also may lead to low-grade inflammation that is associated with obesity [39–42].

Nonetheless, results of the present study did not find a significant association between DII scores and body composition parameters among elite and sub-elite soccer players and referees.

Importantly, studies conducted specifically in athletic populations provide findings that are generally consistent with our results. In a cross-sectional study of 41 female NCAA Division I collegiate athletes from various sports, no significant correlations were found between DII and body composition measures [43]. Body composition, including bone-related parameters, was assessed using Dual-energy X-ray Absorptiometry (DXA), strengthening the reliability of their findings. The authors concluded that neither DII nor overall diet quality was associated with body composition or bone health in female collegiate athletes [43].

Similarly, Al-Rubaye et al. investigated the association between DII and body composition among 100 Paralympic athletes with hemophilia or undergoing hemodialysis and reported no significant association between DII and several body composition parameters [44]. Although the clinical characteristics of these athletes differ from those of the participants in our study, these findings further suggest that the relationship between DII and body composition may not be consistent across athletic populations.

Evidence from professional football players provides another particularly relevant comparison. Kenger et al. evaluated 21 professional male football players exposed to long-term intensive exercise and investigated the relationship between nutritional status, anthropometric characteristics, and DII. Their findings suggested that DII was related to abdominal adiposity, whereas associations with several other anthropometric characteristics were not consistently observed. This pattern may indicate that DII is more likely to be associated with specific patterns of fat accumulation than with overall body size or body composition in highly trained athletes [30].

As demonstrated earlier, research in general populations has more consistently reported positive associations between a pro-inflammatory dietary pattern and adiposity. The discrepancy between athletic and general populations may partly be explained by the physiological effects of regular exercise. Exercise should not simply be considered an anti-inflammatory stimulus; rather, it induces a transient and highly regulated immune response involving both pro-inflammatory and anti-inflammatory cytokines. During strenuous exercise, circulating concentrations of cytokines such as IL-6 can increase substantially, followed by increases in cytokine inhibitors such as IL-1 receptor antagonist (IL-1Ra) and the anti-inflammatory cytokine IL-10. This response is well documented in the exercise-immunology literature [45]. Thus, athletes may experience repeated acute inflammatory responses during

training while simultaneously developing adaptations that facilitate resolution of inflammation and maintenance of immune homeostasis. A particularly important mechanism in this context is the release of IL-6 from contracting skeletal muscle. Unlike chronically elevated IL-6 associated with obesity and metabolic dysfunction, exercise-induced IL-6 functions as a myokine and participates in metabolic and immunoregulatory processes. Prolonged exercise stimulates the transcription and release of IL-6 from contracting skeletal muscle fibers, and this increase is subsequently accompanied by elevations in IL-1Ra and IL-10 [45]. Therefore, the increase in IL-6 during exercise should not necessarily be interpreted as evidence of chronic or detrimental inflammation. Instead, muscle-derived IL-6 appears to be an important component of the adaptive response to exercise.

The exercise-induced cytokine response may therefore attenuate or modify the potential effects of dietary inflammatory exposure on body composition. Exercise-induced IL-6 has been proposed to stimulate anti-inflammatory pathways, including increased IL-10 and IL-1Ra, while inhibiting excessive TNF- α signaling [46]. Consequently, the inflammatory consequences of a particular dietary pattern may depend not only on the inflammatory potential of the diet itself but also on the magnitude and frequency of exercise-induced immune responses. This interaction may be particularly relevant in athletes, who are repeatedly exposed to exercise-induced cytokine signaling [46].

Oxidative stress represents another potential mechanism linking diet, exercise, inflammation, and body composition. Exercise increases reactive oxygen species (ROS) production in contracting skeletal muscle; however, ROS generated during exercise should not be regarded exclusively as detrimental molecules. Rather, transient increases in ROS act as signaling molecules that participate in antioxidant defense, metabolic regulation, mitochondrial adaptation, and exercise-induced physiological adaptations [47]. Powers et al. reviewed the role of exercise-induced oxidative stress and highlighted that ROS can function as important signaling molecules involved in the adaptive response to exercise. Therefore, repeated exercise may enhance the ability of athletes to maintain redox homeostasis and tolerate oxidative challenges, potentially reducing the physiological impact of modest differences in dietary inflammatory potential [47].

Mitochondrial adaptations induced by regular exercise may provide an additional explanation for the absence of a clear association between DII and body composition. Exercise is a powerful stimulus for mitochondrial remodeling and adaptation, influencing mitochondrial content, oxidative phosphorylation, respiratory capacity, and metabolic function [48]. Repeated exercise can increase mitochondrial oxidative capacity and improve the ability of skeletal muscle to utilize different energy substrates. These adaptations may contribute

to improved metabolic flexibility and insulin sensitivity and could partly counterbalance metabolic effects that might otherwise arise from differences in dietary inflammatory potential [48].

The interaction between diet and exercise is particularly relevant in sports nutrition. Athletes have nutritional requirements that differ substantially from those of sedentary populations because dietary intake must support not only health but also high energy expenditure, glycogen restoration, muscle protein turnover, tissue repair, immune function, and training adaptation. Therefore, the inflammatory potential of the diet should be interpreted within the broader context of training load, energy availability, macronutrient intake, and recovery. Importantly, DII represents the inflammatory potential of the diet rather than a direct biomarker of systemic inflammation. Consequently, a relatively pro-inflammatory DII score does not necessarily indicate that an athlete has a pro-inflammatory physiological state. This distinction may be particularly relevant in endurance athletes, who are repeatedly exposed to prolonged exercise and substantial metabolic stress. Prolonged endurance exercise can produce substantial increases in IL-6, followed by increases in IL-10 and IL-1Ra [45]. At the same time, repeated endurance training promotes mitochondrial biogenesis, oxidative capacity, and antioxidant adaptations [47,48]. Thus, the physiological response to a diet with a particular inflammatory potential may differ considerably between a trained endurance athlete and a sedentary individual.

The findings concerning BMC may also be interpreted within this exercise-specific framework. Although previous research in general populations has suggested associations between inflammatory dietary patterns and bone health, athletes are exposed to repeated mechanical loading, which is an important stimulus for bone remodeling and adaptation [49]. Sport-specific mechanical loading, training volume, energy availability, calcium and vitamin D intake, and hormonal status may therefore exert stronger influences on BMC than dietary inflammatory potential alone. The absence of an association between DII and BMC in our study is consistent with the findings of Gieng et al., who also reported no significant relationship between DII and body composition or bone-related parameters in female collegiate athletes assessed using DXA [43].

The specific characteristics of football and other intermittent sports should also be considered when interpreting these findings. Football/soccer players are exposed to a combination of endurance exercise, repeated high-intensity running, sprinting, acceleration and deceleration, and mechanical loading. In professional football players, Kenger et al. observed a relationship between DII and abdominal adiposity, but not necessarily with all anthropometric parameters [30]. This finding may suggest that the potential influence of dietary

inflammatory potential may be phenotype-specific and may not necessarily extend to global measures such as BMI or total body fat. Differences between their findings and ours may also be explained by differences in sample characteristics, dietary assessment methods, training exposure, and body composition outcomes.

It is also worth noting that the dietary patterns of athletes often include supplements, functional foods, and specific timing strategies, which may not be fully captured by traditional DII calculations. Several studies have shown an inverse association between healthy diets and markers of inflammation, as well as a direct association with 'Western-like' dietary pattern [50–56]. Specifically, a lower CRP concentration has been associated with a higher intake of fruits and vegetables [57–59], legumes [60], nuts [61], and low-fat dairy consumption [62]. Previous studies have also observed associations of specific nutrients such as total dietary fiber [63], vitamin E and vitamin C intake [64] with lower levels of inflammatory markers. On the contrary, animal protein seems to increase the inflammatory status of obese individuals [65]. Additionally, healthier lifestyle behaviors such as better sleep quality, stress management, and hydration practices are more common in athletic populations, further reducing the observable influence of dietary inflammation on body composition [66]. These factors collectively may explain the lack of significant association between DII and body composition in our athletic population compared to non-athletics.

Interestingly, no significant difference was found in trans-fat intake across tertiles of DII, which may be attributable to the very low and relatively homogeneous intake of trans-fat among the participants. The mean values were close to zero across all three tertiles, suggesting limited variability in this dietary component. This pattern may partly reflect the relatively high nutritional awareness of athletes and their potential access to dietary guidance from sports nutrition professionals [27–29], which could contribute to limiting the consumption of foods rich in trans-fat.

Overall, the available evidence suggests that the relationship between DII and body composition is likely context-dependent. While studies in general populations have frequently reported associations between a more pro-inflammatory diet and greater adiposity, studies conducted specifically in athletes have generally demonstrated weaker or inconsistent associations [30, 43, 44]. One possible explanation is that the effects of dietary inflammatory potential are superimposed on a complex physiological environment characterized by exercise-induced cytokine signaling, muscle-derived IL-6, enhanced antioxidant capacity, mitochondrial adaptations, and exercise-mediated immune regulation. Nevertheless, these mechanisms should be interpreted cautiously because the cross-sectional design of our study does not allow causal inferences.

From a practical perspective, the absence of significant associations between DII and body composition suggests that DII should not be used as a stand-alone tool for body composition management in soccer players and referees. For coaches and sports dietitians, nutritional strategies should instead consider overall dietary quality, energy and macronutrient adequacy, training demands, and recovery. For athletes, modifying DII alone may not necessarily result in meaningful changes in body composition; therefore, dietary strategies should primarily focus on supporting performance, recovery, and long-term health. Soccer federations may also benefit from providing individualized sports nutrition support and integrating dietary and body composition monitoring into broader athlete health and performance programs. These findings do not imply that DII is irrelevant to athletic health, but rather that its relationship with body composition may be more complex in trained populations.

Future longitudinal and intervention studies in athletes should investigate DII alongside objective measures of training volume and intensity and circulating inflammatory and oxidative stress biomarkers, including IL-6, IL-10, TNF- α , IL-1 β , CRP, and markers of oxidative stress. Such studies may help determine whether DII independently influences body composition or whether its potential effects are substantially modified by exercise-induced metabolic, mitochondrial, and immune adaptations.

Strength and Limitations

Our study has inherent strengths and limitations. A 147-item semi-quantitative FFQ, which has been validated for the Iranian population, was used to assess participants' usual dietary intake. Also, all measurements and interviews were conducted by trained personnel, which eventually lead to lower errors in interviewing, data collection, and data entry. The results of this study are generalizable to both males and females, and, to the best of our knowledge this is the first study that calculated the DII and investigated its association with different body composition parameters in soccer players and referees. However, we must acknowledge limitations that need to be addressed. First, the cross-sectional nature of this study does not permit the assessment of causality. Only a prospective study would provide a better understanding of the association between DII score and body composition. Additionally, our FFQ did not capture all 45 food parameters required for the calculation of the DII, therefore 13 parameters, including alcohol, eugenol, ginger, saffron, turmeric, flavan 3-ol, flavones, flavonols, flavonones, anthocyanidins, isoflavones, thyme/oregano, and rosemary were not assessed. Another limitation of our study is that body composition was assessed using an InBody device rather than DXA, which is considered a reference method. Nevertheless, previous research in collegiate American football athletes

has shown that multifrequency BIA can similarly detect changes in body composition parameters compared with DXA, supporting its utility for body composition assessment in athletic populations [67]. And last but not the least, several potential confounding variables, including training volume, playing position, supplement use, menstrual status in female athletes, competition level, and socioeconomic status were not assessed in the present study. These factors may influence dietary intake, lifestyle behaviors, metabolic health, or body composition and could therefore have contributed to the observed associations. The inability to account for these potential confounders should be acknowledged when interpreting the findings and may have introduced residual confounding. Future studies should consider incorporating these variables into study design and statistical analyses to provide a more comprehensive assessment of the associations examined.

Conclusion

The mean DII score was -0.01, illustrating our soccer players and referees were eating a neutral to mildly anti-inflammatory diet. There were no significant correlations between DII score and different body composition parameters ($P>0.05$). Thus, there is little support for recommending such a diet to the athletic populations in order to improve their body composition and subsequently their athletic performance.

Data Availability Statement

The dataset generated and/or analyzed during the current study is not publicly available because it is owned by Tehran University of Medical Sciences and contains data from human participants. De-identified data may be available from the corresponding author upon reasonable request. Requests for access should be submitted to the corresponding author and will be considered subject to institutional policies, ethical approval, and the protection of participant confidentiality.

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Authors' Contributions

MB and KD drafted the article, participated in the design of the study, contributed to data collection and data analysis. HY and TS contributed in data collection. SS and KD revised the manuscript critically for important intellectual content. All authors read and approved the final version of the manuscript.

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Competing Interests

The authors declare no competing interests related to the present study.

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