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Dietary inflammatory index, physical activity, body composition, and high sensitivity c-reactive protein levels in adolescent athletes in Central Java

Trioni Widyastuti [1], Hardhono Susanto [2], Etika Ratna Noer [3*], Muflihatul Muniroh [2], Nyoman Suci Widyastiti [4]

[1] Nutrition Science Postgraduate Program, Faculty of Medicine, Diponegoro University, Jl. Prof. Sunario No. 13, Tembalang, Tembalang, Semarang, Jawa Tengah 50275, Indonesia.
[2] Department of Physiology, Faculty of Medicine, Diponegoro University, Jl. Prof. Sunario No. 13, Tembalang, Tembalang, Semarang, Jawa Tengah 50275, Indonesia.
[3] Department of Nutrition Science, Faculty of Medicine, Diponegoro University, Jl. Prof. Sunario No. 13, Tembalang, Tembalang, Semarang, Jawa Tengah 50275, Indonesia.
[4] Department of Clinical Pathology, Faculty of Medicine, Diponegoro University, Jl. Prof. Sunario No. 13, Tembalang, Tembalang, Semarang, Jawa Tengah 50275, Indonesia.
* Corresponding Author. E-mail: etikaratna@fk.undip.ac.id

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Abstract: Inflammation is the body's response to tissue damage and infection. Prolonged inflammation can increase the risk of non-communicable diseases, including cardiovascular disease. Some factors that can trigger inflammation are dietary patterns, high physical activity, and body composition. This study examined the correlation between dietary inflammatory index (DII), physical activity, body composition, and high sensitivity C-reactive protein (hs-CRP) levels. It examined differences in characteristics based on gender. This study was a cross-sectional design of 55 adolescent athletes at the Student Sports Education and Training Center in Central Java. The exclusion criteria were an athlete who had a physical injury (did not participate in training) and a smoker. The DII score was calculated based on the dietary pattern using SQFFQ, anthropometric data (weight, height, and nutritional status based on BMI/age), body composition (body fat percentage, fat mass, and fat-free mass) using the BIA tool, physical activity data for the last seven days using IPAQ and hs-CRP levels using the FIA method. Our result showed that the DII score was significantly correlated with hs-CRP ($p=0.013$). There was no correlation between physical activity, body composition, and anthropometry with hs-CRP levels ($p>0.05$). There were differences in body height, body weight, body fat percentage, and fat-free mass between males and females ($p<0.001$). The diet of athletes had anti-inflammatory potential (83.6%), as evidenced by the intake of vitamins and minerals, and athletes had low hs-CRP levels <1 mg/L (85.5%), indicating that no inflammation occurred. Future longitudinal research is needed with a large population of adolescent athletes to explain the role of anti-inflammatory and pro-inflammatory diets on the incidence of inflammation and measure physical exercise in athletes to reduce inflammatory bias.

Keywords: dietary inflammatory index, inflammation, physical activity, athlete

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INTRODUCTION

Inflammation is a body's physiological response that defends against tissue damage and infection to maintain health and recover from injuries (Hart et al., 2021). Inflammation is associated with developing non-communicable diseases, including cardiovascular disease (Tsoupras et al., 2018). This process begins in childhood and can develop and continue throughout life. It shows that anthropometric measurements, lifestyle, and examination of adulthood inflammatory biomarkers can provide health information (Zarzour et al., 2017). C-reactive protein (CRP) can be measured by the highly sensitive method (hs-CRP) and is produced in response to stimulation by interleukin 6 (IL-6) (Cavicchia et al., 2009). It shows that hs-CRP is a sensitive indicator for determining inflammatory conditions. In addition, CRP can indicate an injury from sports or excessive activity (Lee et al., 2017; Pahwa et al., 2023). Excessive physical activity can lead to overtraining syndrome (OTS), with increased production of reactive oxygen species (ROS). Increased ROS due to oxidative stress can trigger the expression of pro-inflammatory markers. Athletes carry out intensive and prolonged physical activity and training, which can cause a change in metabolism and immunity and reduce performance (Cheng et al., 2020; Jahangiri et al., 2019; Luti et al., 2020).

In addition to physical activity, inflammation is also influenced by food intake (Muhammad et al., 2019). Previous studies have found that diet affected inflammatory markers (Cavicchia et al., 2009). The role of diet or nutrient intake can directly increase or suppress inflammation. A dietary assessment called the dietary inflammatory index (DII) has been developed to see the inflammatory status of the food consumed. In DII, nutritional components are calculated and compiled to create an inflammation index score. This index score is associated with systemic inflammation (Shivappa et al., 2014, 2015). A low index score indicates an anti-inflammatory diet and a high index score indicates a pro-inflammatory diet (Hébert et al., 2019). The role of diet becomes essential in the composition of dietary intake, such as the type of food and nutrients consumed. An anti-inflammatory dietary pattern like the Mediterranean diet includes a high intake of vegetables, fruit, and olive oil, which contains high levels of vitamins, minerals, and fibre. The research showed that this diet is safe for improving aerobic performance and strength in adolescent athletes (Helvacı et al., 2023). In addition, this diet can reduce CRP, tumour necrosis factor-alpha (TNF-α), and IL-6 and increase IL-10 levels as an anti-inflammatory cytokine (Griffiths et al., 2022). Dietary patterns that lead to pro-inflammation, such as the Western diet, which is high in saturated fatty acids and carbohydrates, contribute to increased inflammatory markers, especially CRP. The most common cause of diet-related inflammation in the body is high energy consumption associated with body fat (Marx et al., 2021).

In recent years, Body Mass Index (BMI) and body fat percentage have been used to assess athletes' optimal body weight. However, BMI only uses weight and height and does not consider overall body composition, including body fat, so muscular individuals can be classified as obese (Etchison et al., 2011; Torstveit & Sungdot-Borgen, 2012). Body composition, such as body fat percentage, has a negative impact on aerobic and anaerobic capacity, strength, speed, and ability to perform physical activity. In contrast, muscle mass has a positive effect on athletes. In addition, a high percentage of body fat is associated with increased CRP levels (Dunn et al., 2021; Leão et al., 2022). Excess adipose tissue increases IL-6 secretion, increasing CRP secretion (Dunn et al., 2021; Han & Levings, 2013). Additionally, being overweight or obese can reduce anti-inflammatory immune cells in adipose tissue (Muhammad et al., 2019). This study assessed athletes' BMI and body fat percentage to identify the most suggestive values and their correlation with inflammatory events.

Inflammation in athletes is a natural process, but if prolonged, it can become chronic inflammation, which can increase the risk of cardiovascular diseases and decrease athletes' performance (Luti et al., 2020; Passos et al., 2019). The novelty of this study is that it measures the quality of dietary patterns in athletes in Indonesia, which is associated with inflammatory markers. Studies in this area are still scarce in Indonesia. Furthermore, this study examines the association between dietary pattern (DII score), physical activity, body composition, and hs-CRP in adolescent athletes.

METHODS

Research Design

This research was an observational study using a cross-sectional design. It was conducted from January to February 2024 at the Student Sports Education and Training Center in Central Java. Ethics approval has been obtained from the Health Research Ethics Commission of the Faculty of Medicine, Diponegoro University 2024 (Number 008/EC/KEPK/FK-UNDIP/I/2024).

Research Subject

The sample size calculation of this study used the G*Power application, with a minimum sample of 50 athletes. The subjects who participated in the screening process were 70 athletes. The sampling technique was purposive sampling. The inclusion criteria in this study were being athletes for at least one year, not having flu, cough, and fever symptoms, not taking anti-inflammatory drugs, being willing to join this research with the guardian’s approval, and filling out informed consent. Exclusion criteria were athletes who had a physical injury (did not participate in training) and smokers. After screening, 55 athletes were eligible to participate in the study.

Research Instruments

The independent variables of this study were the DII scores, physical activity, and body composition. The dependent variable was hs-CRP. The primary data taken in this study were respondents' identity, dietary patterns, physical activity, body composition, anthropometric data, and hs-CRP levels. Respondent identities were obtained from the Student Sports Education and Training Center, which gave its students consent to participate in the research. Physical activity data was assessed using the International Physical Activity Questionnaire (IPAQ), which was validated in previous studies and contained the duration of several activities, including exercises carried out in the last week (Macek et al., 2019). Anthropometric data taken were body weight using a digital scale with an accuracy of 0.1 kg, body height using a microtoise with an accuracy of 0.1 cm, nutritional status using Body Mass Index (BMI) based on age because the subject is 13-18 years old, and body composition data including body fat percentage, fat mass, and fat-free mass using a Bioimpedance Analysis monitor (BIA) (Campa et al., 2021). High-sensitivity C-reactive protein (hs-CRP) levels were obtained through a blood draw in the morning, and the subject was ensured to have fasted 12 hours before the blood draw. Blood samples were detested using the Fluorescence Immunoassay (FIA) method, which was carried out in a private laboratory in Semarang.

Dietary pattern data were collected by using the Semi-Quantitative Food Frequency Questionnaire (SQ-FFQ) through interviews (Handayani et al., 2020). The results of the SQ-FFQ were then entered into the Nutrisurvey application, which was calculated using a daily intake and then entered into the DII score assessment. A diet was considered pro-inflammatory if the DII score was positive (+) and considered anti-inflammatory if the DII score was negative (-). The score calculation began by subtracting the amount of each nutrient consumed from the global standards average and then dividing by standard deviation. This result was then converted into a percentile score to minimize the right-slope effect by multiplying each score by two and subtracting by 1. The percentile value was then multiplied by the inflammatory effect score on each nutrient to get a DII score. Add up all nutrient scores to get the sum of the DII scores (Shivappa et al., 2014). In this study, 27 of 34 food or nutrient parameters were included in the assessment of the DII score, including energy, carbohydrate, protein, total fat, saturated fat, iron, cholesterol, vitamin B12, omega-3, omega-6, Monounsaturated Fatty Acids (MUFA), Polyunsaturated Fatty Acids (PUFA), fibre, vitamin A, D, E, C, B6, β-carotene, thiamine, riboflavin, niacin, folic acid, magnesium, selenium, zinc, and caffeine (Hébert et al., 2019; Shivappa et al., 2014).

Data Analysis

This research conducted the statistical analysis using SPSS version 22, and the normality of the data was analyzed using Kolmogorov-Smirnov. The variables of height, weight, body fat percentage, fat mass, nutritional status, and DII score were normally distributed. In contrast, the variables of age, physical activity, and hs-CRP levels were not normally distributed. Univariate analysis was employed to identify the general characteristics of the subject, and bivariate analysis was used to investigate the correlation between the independent variable (DII, physical activity, and body composition) and the dependent variable (hs-CRP) using Spearman Rank. Moreover, the Mann Whitney test was done to look for differences in characteristics based on gender for data not normally distributed, and the independent sample test for normally distributed data.

RESULTS AND DISCUSSION

This study examined the correlation between dietary inflammatory index (DII), physical activity, body composition, and high sensitivity C-reactive protein (hs-CRP) levels. This was the first study to assess the association between DII and inflammatory biomarkers in adolescent athletes. Table 1 displays the respondent's characteristic data, which includes anthropometry (age, body height, body weight, and nutritional status), body composition (body fat percentage, fat mass, and fat-free mass), physical activity, hs-CRP levels, and DII score. The age range of respondents was 13–18 years. The average nutritional status of the body mass index based on age was 0.10. Body composition in terms of body fat percentage averages 19.16%. The average fat mass is 12.29 kg, and the fat-free mass is 50.1

kg. The average physical activity using the METs-minutes/week calculation is 8749.10. Most respondents with the same sport have the same physical activity values. The average hs-CRP level in respondents was 0.80 mg/L, which is low, so there is no risk of inflammation. One respondent had a hs-CRP level of 12.73 mg/L, which was excluded from this study. Elevated hs-CRP levels indicate an acute inflammatory response (Dhingra et al., 2007). The average DII score is -0.99, meaning respondents have an anti-inflammatory diet.

Table 1. Subject Characteristics

Subject Characteristics	n	%	Min-Max	Mean ± SD
Age (years)			13 – 18	15.78 ± 1.25
Anthropometrics				
Height (cm)			150.8 – 191.8	170.26 ± 10.32
Body Weight (kg)			37.7 – 104.3	62.48 ± 11.69
Nutritional Status (z-score)			-1.52– 2.91	0.10 ± 0.81
Normal	49	89.1		
Overweight	5	9.1		
Obese	1	1.8		
Body Composition				
Fat mass (kg)			1.3 – 34.5	12.29 ± 6.10
Body fat (kg)			5 – 43	19.16 ± 6.92
Fat Free Mass (kg)			31.7 – 69.8	50.16 ± 9.80
Physical activity (METs-minutes/week)			2415 - 16764	8749.10 ± 4015.63
hs -CRP levels			0.50 – 3.54	0.80 ± 0.67
<1 mg/L	47	85.5		
>1 mg/L	8	14.5		
DII Score			-3.66 – 2.51	-0.99 ± 1.35
Anti-Inflamasi	46	83.6		
Pro-Inflamasi	9	16.4		

The finding shows that the study respondents' dietary intake has relatively high levels of pro-inflammatory components such as total energy, carbohydrates, iron, cholesterol, protein, total fat, and saturated fat, except for vitamin B12. Based on food intake data taken using SQ-FFQ, subjects often consume foods high in energy and fat, such as fish and chicken, processed in fried food. In addition, the dietary intake of subjects with the most anti-inflammatory components, especially vitamins A, D, and C, β-carotene, and zinc. The source of anti-inflammatory components most often consumed by the subject is fruit and vegetables (see Table 2).

Analyses of differences between the two gender groups are shown in Table 3. The results show no age, nutritional status, or fat mass differences between the male and female groups ($p > 0.05$). This study showed that there were significant differences in height and weight ($p<0.001$); the male group had higher height and weight than the female group. These results align with previous research, which reported that males are 13 cm taller and 11.4 kg heavier than females (Mansour et al., 2021). The body composition results of body fat percentage and fat-free mass have a significant difference ($p<0.001$), where the average body fat percentage of 23.4% for females was higher than the body fat percentage of 15% for males. In addition, the fat-free mass of males, with a mean of 57.7 kg, was higher than that of females, with a mean of 42.29 kg. Body composition and nutritional status serve as assessments of health and athletic performance. High body fat could have a negative impact on strength and power, especially in athletes (Ackland et al., 2012; Mansour et al., 2021). Female athletes have weaker muscular volume and a high body fat percentage, which means female athletes never match the physical performance of men (Jagim et al., 2023). Consistent with the literature, we have found that males were taller, heavier, and had less body fat than females.

Table 2. The Average Global Dietary Intake and Dietary Intake of The Study Subject

Intake	Global dietary Intake Mean±SD	Dietary Intake of Study Subject Mean±SD
Pro-Inflammatory Components		
Energi (kl)	2056 ± 338	2450.29 ± 708.40
Carbohydrate (g)	272.2 ± 40	303.41 ± 111.99
Proteins (g)	79.4 ± 13.9	108.66 ± 42.83
Total fat (g)	72.4 ± 29.4	90.86 ± 35.57
Saturated fat (g)	28.6 ± 8	38.80 ± 15.10
Cholesterol (g)	279.4 ± 51.2	432.47 ± 200.41
Iron (mg)	13.35 ± 3.71	21.09 ± 16.71
Vitamin B_{12} (μg)	5.15 ± 2.7	4.78 ± 4.37
Anti-Inflammatory Component		
MUFA (g)	27.0 ± 6.1	25.02 ± 9.80
PUFA (g)	13.88 ± 3.76	19.51 ± 12.74
Omega-3 (g)	1.06 ± 1.06	4.85 ± 6.98
Omega-6 (g)	10.8 ± 7.5	0.62 ± 0.82
Fiber (g)	18.8 ± 4.9	20.52 ±14.06
Vitamin A (μg)	983.9 ± 518.6	1535.46 ± 639.31
Vitamin D (μg)	6.26 ± 2.21	11.04 ± 55.01
Vitamin E (mg)	8.73 ± 1.49	5.02 ± 2.44
Vitamin C (mg)	118.2 ± 43.46	209.52 ± 273.40
Vitamin B_6 (mg)	1.47 ± 0.47	2.38 ± 1.20
β-carotene (μg)	3.71 ± 1.72	5.16 ±7.54
Thiamine (mg)	1.7 ± 0.66	1.35 ± 0.83
Riboflavin (mg)	1.7 ± 0.29	1.85 ± 2.17
Niacin (mg)	25.9 ± 11.77	16.09 ± 6.30
Folic acid (μg)	273 ± 70.7	288.03 ±149.9
Magnesium (mg)	310.1 ± 139.4	446.86 ± 206.32
Selenium (μg)	67 ± 25.1	18.27 ± 13.64
Zinc (mg)	9.84 ± 2.19	12.49 ± 5.50
Caffeine (g)	8.05 ± 6.67	7.87 ± 12.44

Note: SD = Standard deviation

Table 3. Differences by Gender in Mean DII Scores, Physical Activity, Body Composition, and hs-CRP

Variable	Male (n=28) Mean±SD	Female (n=27) Mean±SD	p-value
Age (years)	15.79 ± 1.19	15.78 ± 1.34	0.876[a]
Anthropometrics			
Body Height (cm)	176.65 ± 8.56	163.64 ± 7.46	**0.000[b]***
Body Weight (kg)	68.66 ± 11.79	56 ± 7.4	**0.000[b]***
Nutritional Status (z-score)	0.23 ± 0.96	-0.02 ± 0.63	0.235[b]
Body Composition			
Body fat (%)	15.06 ± 6.55	23.41 ± 4.24	**0.000[b]***
Fat mass (kg)	10.78 ± 6.58	13.86 ± 5.22	0.061[b]
Fat Free Mass (kg)	57.74 ± 7.32	42.29 ± 4.19	**0.000[a]***
Physical activity (METs-minutes/week)	8921.45 ± 4307.55	8570.37 ± 3763.21	0.993[a]
hs -CRP levels	0.99 ± 0.88	0.60 ± 0.20	0.229[a]
DII Score	-1.97 ± 1.23	-1.22 ± 1.69	0.889[b]

[a]Using the Mann-Whitney test [b] Using Independent Samples Test *significant difference $p<0.05$

Note: SD = Standard deviation

In the analysis of differences in physical activity, hs-CRP levels, and DII score, there were no differences according to gender ($p>0.05$). Based on the physical activity in this study, athletes performed the same activity by gender. This can be caused by the fact that male and female athletes in this study have the same type of sport and activities. This study shows that male athletes have a higher average physical activity than female athletes, but there is no significant difference. Hunter et al. (2023) stated that males outperform females in sports and physical activity or athletic that require aerobic endurance, power, muscular strength, and speed. These biological differences lead to a 10%-30% sex difference in athletic performance. This study found that hs-CRP levels did not have significant differences based on gender. There has been no research on hs-CRP levels by gender in athletes, so no literature supports these results. However, studies in healthy adults showed that females have higher hs-CRP levels than males (Khera et al., 2005). Dietary intake assessed by dietary quality in the form of DII score shows no differences based on gender. Female and male athletes have a mean of -1.97 and -1.22, indicating that both groups have an anti-inflammatory diet.

Table 4. Correlation Between DII Scores, Physical Activity, and Body Composition with hs-CRP Levels

Variable	**hs -CRP levels**	
	r value	**p-value**
Anthropometrics		
Height (cm)	0.067	0.114
Body Weight (kg)	0.228	0.080
Nutritional status (BMI/age)	0.209	0.126
Body Composition		
Body fat (%)	-0.013	0.727
Fat mass (kg)	0.088	0.521
Fat Free Mass (kg)	0.151	0.272
Physical activity (METs-minutes/week)	0.116	0.398
DII Score	0.334	**0.013***

used the Spearman Rank Test, *significant correlation p<0.05

This study found no correlation between anthropometry, body composition, and hs-CRP levels with a p-value of >0.05 (See Table 4). This result differs from previous research, which showed that body weight, percentage of body fat, fat-free mass, and nutritional status correlated with a p-value <0.05 (Dunn et al., 2021). Body composition is essential in generating physiological responses in the physical body and health status. Therefore, body composition is highly considered in many sports organizations (Kasper et al., 2021; Sundgot-Borgen et al., 2013). This study found that females have more body fat than males. However, it did not show a significant association with hs-CRP levels. A low body fat percentage was associated with greater antioxidant activity and lower inflammation (Aguiar et al., 2020). Inflammation plays a role in weight gain through leptin and insulin resistance, which can increase body fat mass and CRP and other inflammatory cytokines. Based on this, being overweight and obese are considered low-level inflammatory conditions (Shahinfar et al., 2023). We still found that athletes categorized as overweight and obese had low hs-CRP values. This could be related to the sample athletes who do regular sports and activities.

Regular exercise can reduce the concentration of inflammatory cytokines (Dunn et al., 2021). A systematic review concluded that physical exercise can positively benefit the body by improving cardiovascular, strength, immunity, and endurance (Wijaya et al., 2024). This study found that there is no significant relationship between physical activity and hs-CRP level. This finding aligns with previous research (Rombaldi et al., 2015; Sadeghipour et al., 2010). It is important to note that the physical activity was measured using a self-reported questionnaire, where participants may report inaccurate time and duration. In addition, blood sampling was done in the morning, at rest, or not doing physical activity or low to high-intensity exercise. When hs-CRP levels are within the normal range, exercise and daily physical activity have little effect (Sadeghipour et al., 2010). However, much evidence has shown that physical activity can affect low-grade inflammation and reduce the risk of non-communicable diseases in physically active individuals (Dhuli et al., 2022; Ertek & Cicero, 2012). A decrease in fat mass causes the anti-inflammatory effect of physical activity. Regular exercise/athletes who exercise, which impacts skeletal muscle, use fat more as a substrate during training, as an inflammatory profile that lowers the risk of disease (Burini et al., 2020).

This study found a significant positive association between the DII scores and hs-CRP levels with a value of p=0.013 (p<0.05). These results aligned with the previous studies with large sample sizes, finding a strong association between DII scores and hs-CRP levels. Diet is known to have a role in regulating chronic inflammation (Shivappa et al., 2014). Many factors, including food intake, can influence the inflammation caused by exercise (Bermon et al., 2017). The role of dietary patterns in inflammation is that nutrients can directly suppress or increase inflammation. Besides that, it can also increase or decrease the production of Reactive Oxygen Stress (ROS). Increased ROS impacts inflammatory events that trigger cells to produce pro-inflammatory compounds (Muhammad, 2023).

Some nutrients such as fatty acids, cholesterol, and high energy intake increase inflammation, while vitamins A, B, C, D, and E can reduce inflammation (Muhammad, 2023). The Mediterranean diet was shown to reduce the level of hs-CRP, while the Western diet, characterized by high consumption of red meat and processed meats, was associated with increased hs-CRP levels. (Cavicchia et al., 2009; Ley et al., 2014). The results of previous studies stated that a diet with a high intake of fruit, vegetables, and fish was associated with lower levels of hs-CRP, indicating a reduced risk of cardiovascular disease due to inflammation (Wood et al., 2014). In line with this study, male and female athletes consume fruits and vegetables with many anti-inflammatory components, such as vitamins and minerals. Hence, the diet is anti-inflammatory based on the assessment of the DII scores. In another study, DII scores and hs-CRP levels were significantly positively correlated in males. However, no relationship was found between females' DII score and hs-CRP (Kotemori et al., 2021).

In line with our findings, the most anti-inflammatory diets were found in the group of males, as shown in Table 3. Longitudinal research is needed to examine the role of anti-inflammatory and pro-inflammatory diets with gender-related inflammation in adolescent athletes. Food components are one of the main factors that are important in regulating the state that is important in the body. An athlete's diet is essential in recovery and performance, as well as an athlete's health, especially during childhood and adolescence, most of which will continue into adulthood; therefore, athletes are given special attention to food intake to achieve optimal performance (Baranauskas et al., 2015).

This study has several limitations. Firstly, the design was cross-sectional. Therefore, we cannot conclude the cause and effect between DII scores and hs-CRP levels. Assessment of dietary quality using the DII has yet to be validated for the adolescent athlete population. Pro-inflammatory nutritional components, such as trans fat, were not included in this study due to their limited dietary value in the Nutrisurvey application. Finally, athletes sampled in this study belonged to different sports.

CONCLUSION

This study focused on the correlation between dietary inflammatory index (DII), body composition, physical activity, and hs-CRP levels. The results showed that there is no correlation between body composition and physical activity with hs-CRP. However, the study found a correlation between DII scores and hs-CRP levels. The male group had the most anti-inflammatory diet compared to females, but there was no significant difference. DII scores can be used to measure the correlation between diet and inflammatory events. Future longitudinal studies using large populations of adolescent athletes are warranted to elucidate the role and mechanism of anti-inflammatory and pro-inflammatory diets on inflammatory events. In addition, examining the relationship between DII scores and athletes' performance is necessary.

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