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FROM PLATE TO PLASMA: EVALUATING THE RELATIONSHIP BETWEEN DIETARY INTAKE, INFLAMMATION, AND ANTIOXIDANT POTENTIAL IN YOUNG WOMEN

Muhammad Ali Zahid[1*], Sayyed Usman Hashmi[2], Shafaq Aslam[1], Moha Akram Khan[3], Saira Tanveer[1], Rimsha Fatima[1]

[1] FMH Institute of Allied Health Sciences, Lahore, Pakistan.
[2] Government College University Lahore, Pakistan.
[3] Department of Public Health, University of Health Sciences, Lahore, Pakistan.

***Correspondence Author:** *Muhammad Ali Zahid
*Senior Lecturer, FMH Institute of Allied Health Sciences, Lahore, Pakistan.
Email: ali.zahid@fmhcmd.edu.pk

ABSTRACT

Introduction: Dietary patterns have a profound influence on oxidative stress and systemic inflammation, both of which contribute significantly to the pathogenesis of chronic diseases. In the context of young adults, particularly females pursuing medical education, dietary habits are often compromised, potentially increasing the risk of subclinical inflammation.

Aims & Objectives: This study aimed to evaluate the relationship between Food Quality Score (FQS) and biomarkers of oxidative stress and inflammation among apparently healthy young female students enrolled in various medical universities in Lahore, Pakistan.

Methodology: A cross-sectional analytical study was conducted among 171 female medical university students selected through convenience sampling. Dietary intake data were collected using a validated Food Frequency Questionnaire (FFQ), and FQS was calculated based on the consumption of healthy (fruits, vegetables, nuts, whole grains) and unhealthy (sweetened beverages, fried foods, processed snacks) food groups. Antioxidant capacity of serum and urine was quantified using Ferric Reducing Antioxidant Power (FRAP) and α,α-Diphenyl-β-picrylhydrazyl (DPPH) assays, respectively. Lipid peroxidation was assessed by estimating Malondialdehyde (MDA) using the HPLC method. Inflammatory biomarkers including white blood cell (WBC) and neutrophil counts, mean platelet volume (MPV), red blood cell distribution width (RDW), neutrophil-to-lymphocyte ratio (NLR), platelet-to-lymphocyte ratio (PLR), and RDW-to-platelet ratio (RPR) were measured using fully automated hematological analyzer. Statistical analysis included multivariable logistic regression adjusting for potential confounders.

Results & Findings: Participants with higher FQS demonstrated significantly lower levels of inflammatory hematological markers, including WBC count, RDW, NLR, and PLR ($p < 0.05$). Additionally, higher dietary quality (highest tertile of FQS) was associated with reduced oxidative stress markers, evidenced by significantly lower urinary FRAP (OR_adj = 0.82; 95% CI: 0.70–0.97) and DPPH activity. These associations remained significant after adjusting for potential confounding variables.

Conclusion: The findings of this study highlight that better dietary quality, characterized by higher consumption of nutrient-dense foods and reduced intake of processed and fried foods, is associated with lower levels of systemic inflammation and oxidative stress among young female medical students in Lahore. These results emphasize the need for dietary education and intervention programs targeting medical students to promote healthier eating habits.

Keywords: Food Quality Score, Oxidative Stress, Inflammation, Malondialdehyde, Antioxidants, Medical Students, Lahore, Pakistan

INTRODUCTION

Dietary intake is a fundamental determinant of physiological homeostasis, influencing intricate biochemical and cellular pathways that modulate oxidative stress and systemic inflammation two critical processes underlying the pathogenesis of chronic non-communicable diseases (NCDs) such as cardiovascular disease, metabolic syndrome, neurodegeneration, and certain malignancies [1]. Emerging systematic reviews have highlighted that plant-based dietary patterns particularly Mediterranean and vegetarian diets are inversely associated with biomarkers of oxidative stress (e.g., malondialdehyde, MDA) and inflammatory mediators like CRP and IL-6 [1,2].

Young women engaged in rigorous academic pursuits, such as medical students, frequently exhibit compromised dietary habits driven by stressful and time-restricted environments [3]. These patterns can precipitate subclinical inflammation and oxidative imbalance, detectable through sensitive biomarkers even in the absence of overt clinical disease [3]. Low-grade inflammation and elevated reactive oxygen species (ROS) activity in this demographic may ultimately increase lifelong disease risk if not addressed early.

Evaluation of redox and inflammatory status often relies on biochemical and hematological indices. MDA, measured via high-performance liquid chromatography (HPLC), serves as a validated marker of lipid peroxidation, while assays such as ferric reducing antioxidant power (FRAP) and 2,2-diphenyl-1-picrylhydrazyl (DPPH) reflect systemic antioxidant capacity [4]. Hematological metrics such as white blood cell (WBC) count, red cell distribution width (RDW), neutrophil-to-lymphocyte ratio (NLR), platelet-to-lymphocyte ratio (PLR), and mean platelet volume (MPV) have gained traction as cost-effective, clinically meaningful indicators of systemic inflammation [2].

The Food Quality Score (FQS), a composite index integrating consumption of nutrient-dense foods (fruits, vegetables, whole grains, nuts) and limiting ultra-processed items (sugar-sweetened beverages, fried snacks), offers a robust measure of dietary quality. Although validated predominantly in Western populations, recent data from Iran demonstrate that a higher FQS correlates with lower oxidative stress and inflammatory biomarkers in young women [3].

Despite this, research exploring the FQS–biomarker relationship remains scarce in South Asian populations, especially among female medical students in Pakistan. Given the high academic load and associated lifestyle stressors, this group represents a key target for early nutritional intervention. Understanding how dietary quality impacts inflammatory and oxidative markers in this cohort could guide targeted preventive strategies.

The aims of this study is to evaluate the association between FQS and biomarkers of inflammation (WBC, RDW, NLR, PLR, MPV) and oxidative stress (serum/urinary FRAP, DPPH, and MDA) in apparently healthy female medical university students in Lahore. Using multivariable logistic regression and adjusting for potential confounders, the study seeks to strengthen the evidence base supporting dietary quality as an early predictor of metabolic perturbations and inform nutrition education interventions.

METHODOLOGY

This study employed a cross-sectional analytical design to evaluate the association between dietary quality and biomarkers of oxidative stress and systemic inflammation among young female medical students. A total of 171 participants were recruited through non-probability convenience sampling from multiple medical universities located in Lahore, Pakistan, between January and May 2025.

Inclusion criteria required participants to be female, aged between 18 and 26 years, enrolled in a full-time undergraduate medical degree program, and apparently healthy without known chronic illness or ongoing pharmacological treatment affecting immune or metabolic status. Informed consent was obtained from all participants prior to data collection, and the study protocol received ethical clearance from the institutional review board.

Dietary intake was assessed using a semi-quantitative, culturally adapted and validated Food Frequency Questionnaire (FFQ), which captured the frequency and portion size of commonly consumed food items over the preceding three months [4]. Based on the FFQ data, a Food Quality Score (FQS) was computed for each participant. The scoring system was adapted from previously validated models, assigning positive scores for higher intake of nutrient-dense foods such as fruits, vegetables, legumes, nuts, and whole grains, and negative scores for frequent consumption of low-nutrient, energy-dense foods, including sugar-sweetened beverages, fried foods, refined carbohydrates, and processed snacks [5,6]. Total FQS values were then stratified into tertiles to allow comparison of biomarker outcomes across dietary quality levels.

Peripheral venous blood and early morning urine samples were collected under standardized conditions following an overnight fast. Serum antioxidant capacity was determined using the Ferric Reducing Antioxidant Power (FRAP) assay, while urinary antioxidant activity was assessed through the α,α-Diphenyl-β-picrylhydrazyl (DPPH) radical scavenging assay, both performed using spectrophotometric methods as previously described [7,8]. To quantify lipid peroxidation, the concentration of Malondialdehyde (MDA) was estimated in serum samples via High-Performance Liquid Chromatography (HPLC) using the thiobarbituric acid-reactive substances (TBARS) protocol, calibrated with standard curves to ensure quantification accuracy [6]. Inflammatory and hematological indices were analyzed from ethylenediaminetetraacetic acid (EDTA)-treated whole blood using a fully automated hematological analyzer (e.g., Sysmex XN-series or equivalent). The parameters measured included total white blood cell (WBC) count, neutrophil count, mean platelet volume (MPV), red blood cell distribution width (RDW), and platelet indices. From these, derived ratios such as neutrophil-to-lymphocyte ratio (NLR), platelet-to-lymphocyte ratio (PLR), and RDW-to-platelet ratio (RPR) were calculated, which have been validated as surrogate markers of systemic inflammation in recent clinical epidemiological studies [7].

Data were analyzed using IBM SPSS Statistic. Descriptive statistics (means, standard deviations, frequencies) were used to summarize participant characteristics. Comparisons of oxidative stress and inflammatory biomarkers across FQS tertiles were conducted using one-way ANOVA, for data normality. Multivariable logistic regression models were employed to assess the association between FQS categories and biochemical markers, adjusting for potential confounders including age, BMI, physical activity, and sleep duration. Adjusted odds ratios (OR_adj) and 95% confidence intervals (CI) were reported, and statistical significance was established at $p < 0.05$.

RESULTS & FINDINGS

A total of 171 young female medical students from various universities in Lahore participated in the study. The mean age of participants was 21.8 ± 1.9 years, and the mean BMI was 22.7 ± 3.2 kg/m². Participants were stratified into tertiles based on their Food Quality Score (FQS): Tertile 1 (Low), Tertile 2 (Moderate), and Tertile 3 (High). The distribution of key biochemical and hematological markers across these tertiles is presented below.

Table 1. Demographic and Lifestyle Characteristics of Study Participants (n = 171)

Variable	Category	n (%)
Age (years)	18–19	36 (21.1%)
	20–21	64 (37.4%)
	22–23	49 (28.7%)
	24–26	22 (12.9%)
BMI (kg/m²)	Underweight (<18.5)	21 (12.3%)

	Normal weight (18.5–24.9)	102 (59.6%)
	Overweight (25.0–29.9)	36 (21.1%)
	Obese (≥30.0)	12 (7.0%)
Year of Study	1st year	38 (22.2%)
	2nd year	41 (24.0%)
	3rd year	36 (21.1%)
	4th year	30 (17.5%)
	Final year	26 (15.2%)
Physical Activity (≥3x/week)	Yes	56 (32.7%)
	No	115 (67.3%)
Sleep Duration	<6 hours/day	74 (43.3%)
	6–8 hours/day	81 (47.4%)
	>8 hours/day	16 (9.4%)
Hostel Residency	Hostel resident	89 (52.0%)
	Day scholar	82 (48.0%)
Family History of NCDs	Yes	48 (28.1%)
	No	1231.9%)

The majority of participants (37.4%) were between 20–21 years, aligning with the typical age of MBBS 2nd and 3rd-year students. About 59.6% had normal BMI, while 28.1% were either overweight or obese indicating some level of nutritional imbalance. Nearly 67.3% of students reported no regular physical activity, a factor possibly contributing to oxidative stress and inflammation. Around 43.3% reported sleeping less than 6 hours per night, indicating prevalent academic-related sleep deprivation. Over half the participants (52%) lived in hostels, where dietary patterns often deviate from home-based routines due to limited food choices. Participants were stratified into tertiles based on their Food Quality Score (FQS): Tertile 1 (Low), Tertile 2 (Moderate), and Tertile 3 (High). The distribution of key biochemical and hematological markers across these tertiles is presented below.

Table 2. Distribution of Hematological Inflammatory Markers Across FQS Tertiles

Inflammatory Marker	Low FQS (T1) n=57	Moderate FQS (T2) n=57	High FQS (T3) n=57	p-value
WBC count (×10⁹/L)	8.52 ± 1.43	7.91 ± 1.35	7.31 ± 1.29	0.002*
RDW (%)	14.6 ± 1.1	13.9 ± 1.0	13.3 ± 0.9	<0.001*
NLR	2.53 ± 0.61	2.21 ± 0.54	1.89 ± 0.48	<0.001*
PLR	142.3 ± 24.7	129.6 ± 20.9	117.2 ± 19.1	<0.001*
MPV (fL)	10.6 ± 0.9	10.4 ± 0.8	10.3 ± 0.7	0.183

*Statistically significant at $p < 0.05$

As shown in Table 2, participants in the highest tertile of FQS exhibited significantly lower levels of inflammatory markers. The mean WBC count declined progressively from 8.52 ×10⁹/L in T1 to 7.31 ×10⁹/L in T3 ($p = 0.002$), suggesting lower systemic immune activation in participants with better dietary patterns. Similarly, RDW, NLR, and PLR all showed significant inverse relationships with dietary quality ($p < 0.001$), reinforcing the anti-inflammatory role of high-FQS diets. MPV showed no statistically significant variation.

Table 2. Oxidative Stress and Antioxidant Status Across FQS Tertiles

Biomarker	Low FQS (T1) n=57	Moderate FQS (T2) n=57	High FQS (T3) n=57	p-value
Serum MDA (µmol/L)	4.92 ± 0.83	4.37 ± 0.71	3.98 ± 0.68	<0.001*

Urinary FRAP (µmol/L)	105.8 ± 17.6	96.3 ± 15.2	89.5 ± 13.8	0.001*
Urinary DPPH (%)	45.6 ± 7.8	42.2 ± 6.7	39.1 ± 6.1	0.003*

Table 2 indicates that higher FQS was associated with a significant reduction in oxidative stress. The mean MDA level, a lipid peroxidation marker, was significantly lower in the high-FQS group (T3) compared to the low-FQS group (T1) ($p < 0.001$). Likewise, urinary FRAP and DPPH activity, both indicators of antioxidant potential, decreased in a dose-response manner across tertiles. Lower FRAP and DPPH activity in urine reflect higher systemic antioxidant availability, as these assays represent residual scavenging capacity. Logistic regression analysis further supported this trend.

Table 3. Multivariable Logistic Regression for Low Oxidative Stress (Urinary FRAP)

Variable	Adjusted OR	95% CI	p-value
High FQS (T3 vs T1)	0.82	0.70 – 0.97	0.017*
Age	0.94	0.83 – 1.06	0.314
BMI	1.02	0.98 – 1.07	0.264
Sleep <6 hours/day	1.26	0.89 – 1.85	0.178
Physical inactivity	1.39	0.91 – 2.13	0.113

In multivariable logistic regression analysis (Table 3), high FQS was significantly associated with lower odds of elevated urinary FRAP levels (OR_adj = 0.82; 95% CI: 0.70–0.97; $p = 0.017$), after controlling for age, BMI, physical inactivity, and sleep duration. Other covariates showed no statistically significant associations, reinforcing the independent contribution of dietary quality to oxidative stress modulation.

DISCUSSION

This study assessed the association between dietary quality measured by the Food Quality Score (FQS) and biomarkers of oxidative stress and systemic inflammation among young female medical students in Lahore. The findings revealed a statistically significant inverse relationship between higher FQS and levels of inflammatory and oxidative stress markers. These results provide compelling evidence that adherence to healthier dietary patterns may play a protective role against chronic low-grade inflammation and oxidative stress in young women, particularly those exposed to academic stress and lifestyle irregularities, as often observed among medical students. The inverse association between FQS and inflammatory hematological markers, including white blood cell count (WBC), red cell distribution width (RDW), neutrophil-to-lymphocyte ratio (NLR), and platelet-to-lymphocyte ratio (PLR), is consistent with previous literature emphasizing the anti-inflammatory potential of nutrient-dense foods [12]. Diets high in fruits, vegetables, whole grains, and nuts provide an abundance of antioxidants and phytochemicals, which have been shown to suppress pro-inflammatory cytokine expression and modulate immune responses [13]. Healthy dietary habits reduce visceral adiposity and improve metabolic regulation, which further dampens systemic inflammation [14].

The consumption of unhealthy food groups such as fried items, sugar-sweetened beverages, and processed snacks elements that negatively impact FQS has been associated with elevated levels of inflammation and oxidative stress. These dietary components are rich in trans fats, simple sugars, and advanced glycation end products (AGEs), which are known to promote oxidative damage through mitochondrial dysfunction and increased reactive oxygen species (ROS) production [15]. Our study also demonstrated that higher dietary quality was significantly associated with reduced oxidative stress, as reflected by lower urinary FRAP and DPPH values. These results align with prior research that found diets high in polyphenol-rich foods such as berries, green tea, and leafy greens enhance endogenous antioxidant capacity and scavenge free radicals [16,17]. The FRAP and DPPH assays are reliable indicators of total antioxidant potential in biological samples and their reduction among individuals with better FQS indicates the systemic impact of diet on oxidative defense mechanisms. Lipid peroxidation measured via malondialdehyde (MDA) levels did not show significant variation across dietary tertiles in this study. This could be attributed to the short half-life and metabolic

variability of MDA or limitations in dietary recall accuracy and biological variability. Other studies have similarly found mixed outcomes with MDA in younger populations where baseline oxidative stress levels are generally low [18]. The hematological markers used in this study such as MPV, NLR, and RDW are increasingly recognized as surrogate indicators of systemic inflammation, especially in non-clinical populations. The significant decrease in these markers with improved diet quality in our cohort suggests that diet may influence inflammatory homeostasis even before overt disease manifestations occur [19]. The observed associations remained robust after adjusting for potential confounders, including BMI and physical activity, reinforcing the independent effect of dietary quality on health markers.

These findings are particularly relevant for female medical students in urban centers like Lahore, who often face academic stress, irregular sleep patterns, and suboptimal food choices due to time constraints and hostel living. Targeted nutrition education programs emphasizing affordable, accessible, and health-promoting dietary choices could mitigate the long-term cardiometabolic risks posed by such stressors [20]. This study contributes to a growing body of literature suggesting that dietary interventions promoting whole, plant-based foods and limiting ultra-processed items can significantly reduce subclinical inflammation and oxidative stress among young adults. Longitudinal studies and randomized dietary trials are warranted to confirm these findings and explore the mechanistic pathways further.

Conflict of Interest: The authors declare no conflict of interest related to this study.

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