

# Association of a Dietary Inflammatory Index With Inflammatory Indices and Metabolic Syndrome Among Police Officers

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**Objectives:** To determine whether the dietary inflammatory index (DII) is associated with inflammatory or metabolic biomarkers and metabolic syndrome (MetSyn) among police officers. **Methods:** Cross-sectional data from the Buffalo Cardio-Metabolic Occupational Police Stress study were derived from saliva and fasting blood samples, anthropometric measurements, long-term shiftwork histories, and demographic, stress/depression, and food frequency questionnaires (FFQs). Metabolic syndrome was defined using standard criteria. **Results:** Officers in DII quartiles 2 to 4 were more likely to exceed a threshold of 3.0 mg/L for C-reactive protein (odds ratio [OR] = 1.88; 95% confidence interval [95% CI] = 1.02 to 3.45; OR = 2.17; 95% CI = 1.19 to 3.95; OR = 1.57; 95% CI = 0.85 to 2.88, respectively) compared with quartile 1. The glucose intolerance component of MetSyn was more prevalent among officers in DII quartile 4 than among those in quartile 1 (OR = 2.03; 95% CI = 1.08 to 3.82). **Conclusions:** A pro-inflammatory diet was associated with elevated CRP and with the glucose intolerance component of MetSyn.

Chronic inflammation, as indicated by increases in serum inflammatory mediators such as C-reactive protein (CRP), is a risk factor for numerous chronic disorders such as diabetes, cardiovascular disease (CVD), cancer, and metabolic syndrome (MetSyn).<sup>1</sup> Healthy diets (eg, Mediterranean diets high in fruits and vegetables) typically have been associated with lower inflammation levels (eg, as

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indicated by CRP), whereas Western-style diets (eg, high in fat and simple carbohydrates) have been associated with higher CRP levels.<sup>2</sup>

The dietary inflammatory index (DII) was developed to characterize an individual's diet on a continuum from maximally anti- to pro-inflammatory.<sup>3</sup> Using data from the Seasonal Variation of Blood Cholesterol Study (SEASONS), the newest version of the DII produced an odds ratio (OR) of 1.08 (95% confidence interval [95% CI] = 1.01 to 1.16) for predicting CRP more than 3.0 mg/L (vs  $\leq$ 3.0 mg/L) for each one-unit increase in the DII (corresponding to  $\approx$ 7% of its global range) on the basis of a 24-hour dietary recall, and an OR of 1.10 (95% CI = 1.02 to 1.19) for a 7-day recall.<sup>4</sup> Nevertheless, the DII has not been used to examine diet and intermediate disease endpoints (eg, inflammation) among police officers. Not only do police officers suffer disproportionately from various health conditions,<sup>5</sup> but they also experience life-threatening situations, psychological disturbances including posttraumatic stress disorder, as well as shift-work, fatigue, and sleep deprivation.<sup>6,7</sup>

Shiftwork is a potential occupational stressor that has been associated with increased consumption of calories, fat, protein, carbohydrates, and sweets with lower vegetable and fruit consumption among several studies, and may explain increases in inflammation observed among shiftworkers.<sup>8,9</sup> In addition, repeated exposure to a variety of stressors can lead to changes in food consumption (eg, foods high in sugar, fat, and energy), perhaps because of the generation of negative emotions elicited by stress that can lead to changes in body mass index (weight in kilogram/height in squared meters) and alter several interrelated physiologic processes such as blood pressure, lipid dysregulation, and elevated inflammation that can lead to increased disease risk.<sup>10-12</sup> Therefore, occupational stressors associated with police work modify the relationship between diet and MetSyn or inflammation. We hypothesized that police officers with more pro-inflammatory diets (ie, higher DII scores) would have elevated measures of MetSyn or inflammation compared with those with lower DII scores. We further hypothesized that stress or shift-work may modify this relationship.

## METHODS

Participants included officers from the Buffalo Cardio-Metabolic Occupational Police Stress (BCOPS) cohort ( $n = 464$ ). The BCOPS cohort provides a framework for examining biological processes through which stressors associated with police work may mediate adverse health outcomes.<sup>13</sup> The study received Institutional Review Board approval from The State University of New York at Buffalo, the National Institute for Occupational Safety and Health, and the University of South Carolina. All subjects provided informed consent. Participants were examined on the morning of a scheduled training day or day off. Data collection included long-term shiftwork histories, basic demographics, anthropometrics, and several validated stress/depression questionnaires (Impact of Events, Spielberger Police Stress Survey, Center for Epidemiologic Studies Depression Scale, and Perceived Stress Scale).<sup>13</sup> Frequency and amount of food consumption, on the basis of a validated food

frequency questionnaire (FFQ) developed by the Fred Hutchinson Cancer Research Center for Nutritional Analysis, was used to estimate usual dietary intake of specific micro- and macronutrients (food parameters). Methods for calculation of the DII from these food parameters have previously been described.<sup>3</sup> Briefly, food parameters derived from the FFQ were assigned “article” scores on the basis of research summarizing findings from 1943 articles.<sup>3</sup> A world mean and standard deviation for these food parameters was derived from 11 nutritional databases from around the world. The “standard world mean” was subtracted from the actual dietary intake amount and divided by its standard deviation. This z-score was then converted to a percentile and centered by doubling the value and subtracting 1, which was multiplied by the article score and then summed across all food parameters to create the overall DII score. The greater the DII score, the more pro-inflammatory the diet; more negative values represent more anti-inflammatory diets. DII values were converted to quartiles (quartile 1 = -6.27 to -1.26; quartile 2 = -1.25 to 0.74; quartile 3 = 0.74 to 2.63; and quartile 4 = 2.64 to 5.89). Officers were assigned to the shift on which they spent most of their time (ie, day, evening, or night shifts) using data from the City of Buffalo, NY, daily electronic payroll records from 1994 or initiation of employment until their examination date (during 2004 to 2009).<sup>7</sup>

Saliva samples were used to characterize waking and diurnal cortisol measures that serve as biomarkers of the hypothalamic-pituitary-adrenal axis function.<sup>7</sup> Standard laboratory assays were performed to quantify inflammatory (ie, CRP, interleukin-6, and tumor necrosis factor- $\alpha$ ) and metabolic biomarkers (ie, insulin, adiponectin, and leptin), high-density lipoprotein (HDL) cholesterol, triglycerides, and glucose concentrations in blood. MetSyn criteria were based on the National Cholesterol Education Program Adult Treatment Panel guidelines with recent modifications from the American Heart Association and the National Heart, Lung, and Blood Institute.<sup>14</sup> Individual MetSyn components include waist circumference, hypertension, HDL cholesterol, triglycerides, and glucose intolerance. Metabolic syndrome was considered present if officers met criteria for 3 or more components.<sup>14</sup>

Analyses were performed using SAS software (version 9.3, Cary, NC). Variable selection was based on backward elimination from a “full” model for each dependent variable. Values for interleukin-6, triglycerides, insulin, and leptin were log-transformed to normalize the distribution of the model residuals; all other biomarkers were untransformed. Adjusted (least squares) means in the upper DII quartiles of each biomarker were compared with the first DII quartile using the generalized linear model procedure. Unconditional multiple logistic regression was used to calculate ORs and 95% CIs for dichotomous MetSyn outcomes. C-reactive protein was also categorized as 3.0 mg/L or less or more than 3.0 mg/L, which has been shown to be associated with increased CVD risk.<sup>15</sup> The primary comparisons of interest were between DII quartiles 1 and 4. Shift status (day vs evening/night), years of police work, and self-reported stress were examined as possible effect modifiers.

## RESULTS

Of a total of 464 police officers, 447 had relevant dietary information for DII calculation. The study population was primarily white (79%), non-Hispanic (91%), and male (75%). A majority of the officers had at least some secondary education (88%), held the rank of police officer (65%) compared with other ranks (eg, captain or detective), did not use tobacco (73%), and were overweight (mean body mass index =  $29.3 \pm 4.8 \text{ kg/m}^2$ ). The average age of the population was  $42.4 \pm 8.5$  years, with an average of  $15.7 \pm 8.3$  years of police experience. The percentages of day, evening, and night shiftworkers were 43%, 33%, and 23%, respectively.

No statistically significant mean differences between the upper and lower DII quartiles were observed for any of the individual inflammatory biomarkers, cortisol measures, HDL cholesterol, triglycerides, glucose, adiponectin, or leptin. Mean insulin tended to be lower among those in the lowest DII quartile than among those in the highest (5.7 uU/mL vs 6.7 uU/mL, respectively,  $P = 0.10$ ; Table 1). When CRP was dichotomized, the odds of having a CRP value more than 3.0 mg/L ( $n = 141$ ) among those in DII quartiles 2, 3, and 4 were 1.88 (95% CI = 1.02 to 3.45), 2.17 (95% CI = 1.19

**TABLE 1.** Adjusted Mean (95% Confidence Interval) Inflammatory and Metabolic Markers by Dietary Inflammatory Index Quartiles

Dependent Variables	Quartile 1 <-1.26 Mean (95% CI)	Quartile 2 <0.71 Mean (95% CI)	Quartile 3 <2.50 Mean (95% CI)	Quartile 4 ≥2.50 Mean (95% CI)	P 1 vs 4
CRP, mg/L*	1.5 (1.2–1.8)	1.6 (1.3–2.0)	1.9 (1.5–2.3)	1.4 (1.2–1.8)	0.83
IL-6, pg/mL*	1.7 (1.5–1.9)	1.7 (1.5–1.9)	1.7 (1.5–2.0)	1.7 (1.5–1.9)	0.86
TNF- $\alpha$ , pg/mL	5.0 (4.6–5.4)	5.1 (4.7–5.5)	4.7 (4.3–5.1)	4.7 (4.3–5.1)	0.21
Waking AUC <sub>I</sub> , nmol/L·min	126 (61–190)	203 (135–271)	118 (51–185)	149 (83–215)	0.62
Waking AUC <sub>G</sub> , nmol/L·min	617 (542–692)	665 (588–743)	666 (586–746)	660 (586–735)	0.40
Diurnal AUC <sub>G</sub> , nmol/L·min	5,704 (4,943–6,465)	5,825 (5,096–6,554)	5,643 (4,890–6,397)	5,766 (5,034–6,499)	0.89
HDL cholesterol, mg/dL	51 (48–54)	50 (48–53)	51 (49–54)	50 (48–53)	0.62
Triglycerides, mg/dL*	89 (76–103)	82 (71–96)	78 (67–92)	91 (78–105)	0.79
Glucose, mg/dL	91 (88–93)	92 (90–95)	92 (90–95)	93 (91–96)	0.08
Insulin, uU/mL*	5.7 (4.7–6.9)	6.0 (4.9–7.2)	5.9 (4.8–7.1)	6.7 (5.6–8.2)	0.10
Adiponectin, ng/mL	14,935 (13,579–16,291)	14,186 (12,846–15,527)	14,529 (13,167–15,932)	14,541 (13,248–15,834)	0.65
Leptin, pg/mL*	8,819 (7,074–10,992)	11,552 (9,241–14,442)	12,967 (10,385–16,190)	9,626 (7,768–11,929)	0.55

\*Values were logged and least squares means were back-transformed for presentation.

Adjustments: CRP = age, education, and PSQI; fibrinogen = age, race, PSQI, and SPPS score; IL-6 = rank, years of police work, and alcohol drinks per week; TNF- $\alpha$  = age, race, and sex; waking AUC<sub>I</sub> = amount of moderate to intense physical activity per week, PSQI, and PSS; waking AUC<sub>G</sub> = sex, amount of moderate to intense physical activity per week, and IES; diurnal AUC<sub>G</sub> = ethnicity and IES; HDL cholesterol = sex, alcohol drinks per week, amount of moderate to intense physical activity per week, and SPPS; triglycerides = race, rank, sex, PSQI, and CESD; glucose = age, rank, and sex; insulin = age, ethnicity, sex, tobacco use, and PSQI; adiponectin = race, sex, years of police work, tobacco use, amount of moderate to intense physical activity per week, and SPPS; leptin = age, race, sex, and PSQI.

AUC<sub>I</sub>, area under the curve with respect to increase; AUC<sub>G</sub>, area under the curves with respect to ground; CESD, Center for Epidemiologic Studies Depression; CI, confidence interval; CRP, C-reactive protein; HDL, high-density lipoprotein; IES, Impact of Events; IL, interleukin; PSQI, Pittsburgh Sleep Quality Index; PSS, Perceived Stress Scale; SPPS, Spielberger Police Stress Survey; TNF, tumor necrosis factor.

to 3.95), and 1.57 (95% CI = 0.85 to 2.88) times greater, respectively, compared with those in DII quartile 1, after adjustment for education, and sleep quality (Table 1).

About 28% of the population had MetSyn with 34%, 40%, 42%, 31%, and 26% meeting the definition for the waist circumference, blood pressure, HDL cholesterol, triglycerides, and glucose intolerance components, respectively. There was no statistically significant association between MetSyn and the DII. Nevertheless, the odds of meeting the glucose intolerant component of MetSyn was 2.03 (95% CI = 1.08 to 3.82) times greater among those in DII quartile 4 than among those in quartile 1 (Table 2). Shift status, years of police work, or self-reported stress measures did not modify the hypothesized associations.

## DISCUSSION

We found that, among police officers in the BCOPS study, higher DII scores were associated with elevated CRP values and the glucose intolerance component of MetSyn, independent of stress

indicators. Compared with our findings from the SEASONS, which is primarily a European-American, highly-educated population, we found a larger percentage of individuals with CRP values more than 3.0 mg/L (31% vs 18%, respectively).<sup>4</sup> Nevertheless, in both studies, statistically significant associations were only observed between the DII and CRP as a dichotomous variable.<sup>4</sup> This may reflect a nonlinear relationship between CRP and diet, which also has been observed using other dietary indices such as the Healthy Eating Index.<sup>16</sup> On the basis of statements from the Centers for Disease Control and Prevention and the American Heart Association, CRP values more than 3.0 mg/L represent the high-risk tertile among adults and exhibit approximately twofold increased CVD risk.<sup>15</sup> A statistically significant increased odds of elevated CRP was observed only for DII quartiles 2 and 3 but not for quartile 4 in comparison with quartile 1. Social desirability bias, which is most pronounced in individuals eating more calorie-dense foods (which are pro-inflammatory), may help explain this result.<sup>17</sup> Unfortunately, we had no information on either social approval or social desirability to evaluate this possibility.

**TABLE 2.** Crude and Adjusted Odds Ratios (95% Confidence Interval) for Metabolic Syndrome and Its Components by Quartiles of the DII\*

DII Quartiles	Present n (%)	Absent n (%)	Crude OR (95% CI)	Adjusted OR (95% CI)
Metabolic syndrome				
1	32 (26)	79 (25)	1.0 (Referent)	1.0 (Referent)
2	33 (26)	78 (24)	1.04 (0.59–1.86)	1.10 (0.59–2.04)
3	32 (26)	80 (24)	0.99 (0.55–1.76)	0.92 (0.50–1.71)
4	28 (22)	82 (26)	0.84 (0.47–1.53)	0.87 (0.46–1.63)
Waist circumference component				
1	36 (24)	76 (26)	1.0 (Referent)	1.0 (Referent)
2	34 (23)	77 (26)	0.93 (0.53–1.64)	0.98 (0.54–1.77)
3	46 (31)	66 (22)	1.47 (0.85–2.54)	1.43 (0.81–2.53)
4	34 (23)	78 (26)	0.92 (0.52–1.62)	0.93 (0.52–1.67)
Blood pressure component				
1	45 (25)	67 (25)	1.0 (Referent)	1.0 (Referent)
2	46 (25)	65 (24)	1.05 (0.62–1.80)	1.07 (0.60–1.91)
3	44 (24)	68 (26)	0.96 (0.56–1.65)	1.02 (0.57–1.82)
4	46 (25)	66 (25)	1.04 (0.61–1.77)	1.14 (0.64–2.02)
HDL cholesterol component				
1	47 (25)	64 (25)	1.0 (Referent)	1.0 (Referent)
2	47 (25)	64 (25)	1.00 (0.59–1.70)	1.04 (0.59–1.83)
3	41 (22)	71 (27)	0.79 (0.46–1.35)	0.66 (0.38–1.17)
4	50 (27)	60 (23)	1.14 (0.67–1.93)	1.03 (0.59–1.83)
Triglycerides component				
1	38 (28)	73 (24)	1.0 (Referent)	1.0 (Referent)
2	33 (24)	78 (25)	0.81 (0.46–1.43)	0.81 (0.44–1.48)
3	35 (26)	77 (25)	0.87 (0.50–1.53)	0.83 (0.46–1.50)
4	30 (22)	80 (26)	0.72 (0.41–1.28)	0.77 (0.42–1.42)
Glucose component				
1	24 (21)	88 (27)	1.0 (Referent)	1.0 (Referent)
2	25 (22)	86 (26)	1.07 (0.57–2.01)	1.10 (0.57–2.14)
3	29 (25)	83 (25)	1.28 (0.69–2.38)	1.25 (0.66–2.39)
4	37 (32)	73 (22)	1.86 (1.02–3.39)	2.03 (1.08–3.82)

\*Quartile ranges are as follows: quartile 1 = -6.27 to -1.26; quartile 2 = -1.25 to 0.74; quartile 3: 0.74 to 2.63; and quartile 4 = 2.64 to 5.89. Column percentages may not equal 100% because of rounding.

Adjustments: metabolic syndrome = age and sex; waist circumference (males:  $\geq 102$  cm; females:  $\geq 88$  cm) = sex and years of police work; blood pressure (systolic:  $\geq 130$  mm Hg; diastolic:  $\geq 85$  mm Hg or reported diagnosed hypertension or antihypertensive medication) = age, sex, and alcohol drinks per week; HDL cholesterol (males:  $< 40$  mg/dL; females:  $< 50$  mg/dL or reported treatment with nicotinic acid or fibrates) = race, sex, and alcohol drinks per week; triglycerides ( $\geq 150$  mg/dL) = race and sex; glucose ( $\geq 100$  mg/dL or reported treatment for diabetes) = age and sex.

CI, confidence interval; DII, dietary inflammatory index; HDL, high-density lipoprotein; OR, odds ratio.

A recent review concluded that Western-style diets (linked to higher inflammation) have been associated with increased MetSyn risk in most studies, whereas the Mediterranean diet (associated with lower inflammation) tends to be associated with decreased MetSyn risk.<sup>18</sup> The proportion of officers with MetSyn was only slightly greater than the MetSyn prevalence observed using nationally representative National Health and Nutrition Examination Survey (NHANES) data (28% vs 22%, respectively).<sup>19</sup> One possible explanation for the lack of an association between the DII and the overall MetSyn definition could be the lack of adjustment for other potential confounders (eg, exercise and social desirability), or an insufficient duration of exposure to pro-inflammatory diets in this population. Also, those with highly pro-inflammatory diets may suffer from health consequences that could lead to cardiometabolic interventions or treatments (eg, medication use or exercise), which could reduce the risk of meeting criteria for MetSyn among those in higher DII quartiles. Nevertheless, we did observe an association between the DII and the glucose intolerance component, which happened to contribute the least to MetSyn diagnosis (only 26% of officers met criteria for this component, whereas 31% to 42% met criteria for the other components). Also, the crude mean DII score seemed to be slightly lower among this BCOPS cohort ( $0.59 \pm 2.55$ ) compared with individuals from the SEASONS ( $0.84 \pm 1.99$ )<sup>4</sup> and NHANES ( $0.87 \pm 1.08$ ).<sup>20</sup> A “healthy worker effect” expressed as a less inflammatory diet compared with the general population may also have attenuated the relationship between DII scores and MetSyn, especially considering the mean work duration of police officers in this study was approximately 16 years.

Stress, as measured by self-reported questionnaires, and shift-work status did not modify the associations as hypothesized. Post-hoc analyses indicated no linear association between the DII and the Impact of Events, Spielberger Police Stress Survey, Perceived Stress Scale, or Center for Epidemiologic Studies Depression scale. Shiftworkers in the NHANES had higher DII scores compared with day workers ( $1.01$  vs  $0.86$ ;  $P = 0.01$ ).<sup>20</sup> Although a larger difference was observed in this study, the difference in mean DII values between shiftworkers and nonshiftworkers was not statistically significant ( $0.99$  vs  $0.67$ , respectively;  $P = 0.32$ ), possibly because of a limited sample size.

This is the first study to date to apply the DII to the study of MetSyn in a defined cohort of workers. The BCOPS study is a well-characterized cohort with information on detailed work history, diet, and a variety of biological outcomes. In addition, we were able to examine numerous demographic, anthropometric, behavioral, and stress factors as potential effect modifiers or confounders. Given the cross-sectional nature of this analysis, it is not possible to discern whether associations are causal. Despite these shortcomings, the DII serves as a useful instrument to assess the impacts of diet on inflammatory processes and may serve as a novel tool for better informing dietary interventions among occupational populations. Future studies should apply the DII to assess the role of diet on other inflammation-related chronic disorders such as CVD, diabetes, and cancer.

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