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Association of a Dietary Inflammatory Index with Inflammatory Indices and the Metabolic Syndrome among Police Officers

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Abstract

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. MetSyn was defined using standard criteria.

Results—Officers in DII quartiles 2–4 were more likely to exceed a 3.0mg/L threshold for C-reactive protein (odds ratio [OR]=1.88, 95% confidence interval [95%CI]=1.02–3.45; OR=2.17, 95%CI=1.19–3.95; OR=1.57, 95%CI=0.85–2.88, respectively) compared to quartile 1. The glucose intolerance component of MetSyn was more prevalent among officers in DII quartile 4 compared to quartile 1 (OR=2.03, 95%CI=1.08–3.82).

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Conclusions—A pro-inflammatory diet was associated with elevated CRP and with the glucose intolerance component of the MetSyn.

Introduction

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) (1). Healthy diets (e.g., Mediterranean diets high in fruits and vegetables) typically have been associated with lower inflammation levels (e.g., as indicated by CRP); whereas Western-style diets (e.g., high-fat and simple carbohydrate) have been associated with higher CRP levels (2).

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

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 (8, 9). Additionally, repeated exposure to a variety of stressors can lead to changes in food consumption (e.g., foods high in sugar, fat, and energy), perhaps due to the generation of negative emotions elicited by stress that can lead to changes in body mass index [BMI=weight(kg)/height(m)^2] and alter several inter-related physiologic processes such as blood pressure, lipid dysregulation, and elevated inflammation that can lead to increased disease risk (10–12). 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 (i.e., higher DII scores) would have elevated measures of MetSyn or inflammation relative to those with lower DII scores. We further hypothesized that stress or shiftwork 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 (13). 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 [IES], Spielberger Police Stress Survey [SPPS], Center for Epidemiologic Studies Depression Scale [CESD], Perceived Stress Scale [PSS]) (13). Frequency and amount of food consumption, based on a validated food frequency questionnaire 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 been previously described (3). Briefly, food parameters derived from the FFQ were assigned 'article' scores based on research summarizing findings from 1,943 articles (3). 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 (i.e., 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 2004–2009) (7).

Saliva samples were used to characterize waking and diurnal cortisol measures that serve as biomarkers of the HPA axis function (7). Standard laboratory assays were performed to quantify inflammatory (i.e., CRP, interleukin-6 [IL-6], and tumor necrosis factor-α) and metabolic biomarkers (i.e., 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 (14). Individual MetSyn components include waist circumference, hypertension, HDL cholesterol, triglycerides, and glucose intolerance. MetSyn was considered present if officers met criteria for ≥3 components (14).

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 IL-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 to the first DII quartile using the generalized linear models procedure. Unconditional multiple logistic regression was used to calculate ORs and 95%CIs for dichotomous MetSyn outcomes. CRP also was categorized as ≤3.0 mg/L or >3.0 mg/L, which has been shown to be associated with increased CVD risk (15). 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

Out 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 to other ranks (e.g., captain or detective), did not use tobacco (73%), and were overweight (mean BMI: 29.3±4.8 kg/m^2). The average age of the population was 42.4±8.5 years with an average of 15.7±8.3 years of police experience. The percentages of day, evening and night shift workers 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 compared to the highest (5.7 vs. 6.7uU/mL, respectively, p=0.10; Table 1). When CRP was dichotomized, the odds of having a CRP value >3.0mg/L (n=141) among those in DII quartiles 2, 3 and 4 were 1.88 (95%CI=1.02–3.45), 2.17 (95%CI=1.19–3.95), and 1.57 (95%CI=0.85–2.88) times greater, respectively, compared to those in DII quartile 1, after adjustment for age, 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. However, the odds of meeting the glucose intolerant component of MetSyn was 2.03 (95%CI=1.08–3.82) times greater among those in DII quartile 4 compared to 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 to our findings from the SEASONS study, which is primarily a European-American, highly-educated population, we found a larger percentage of individuals with CRP values >3.0mg/L (31% vs. 18%, respectively) (4). However, in both studies, statistically significant associations were only observed between the DII and CRP as a dichotomous variable (4). 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 (16). Based on statements from the Centers for Disease Control and Prevention and the American Heart Association, CRP values >3.0mg/L represent the high-risk tertile among adults and exhibit ≈2-fold increased CVD risk (15). A statistically significant increased odds of elevated CRP was observed only for DII quartiles 2 and 3 but not quartile 4 in comparison to quartile 1. Social desirability bias, which is most pronounced in individuals eating more calorie-dense foods (which are pro-inflammatory) may help to explain this result (17). Unfortunately, we had no information on either social approval or social desirability to evaluate this possibility.

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 (18). The proportion of officers with MetSyn was only slightly greater than the MetSyn prevalence observed using nationally representative NHANES data (28% vs. 22%, respectively) (19). One possible explanation for the lack of an association between the DII and the overall MetSyn definition could be lack of adjustment for other potential confounders (e.g., exercise, 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 cardio-metabolic interventions or treatments (e.g., medication use or exercise), which could reduce the risk of meeting criteria for MetSyn among those in higher DII quartiles. However, 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 31–42% met criteria for the other components). Also, the crude mean DII score appeared to be slightly lower among this BCOPS cohort (0.59±2.55) compared to individuals from the SEASONS study (0.84±1.99) (4) and National Health and Nutrition Examination Survey (NHANES: 0.87±1.08) (20). A "healthy worker effect" expressed as a less inflammatory diet compared to the general population also may have attenuated the relationship between DII scores and Metsyn, especially considering the mean work duration of police officers in this study was ≈16 years.

Stress, as measured by self-reported questionnaires, and shiftwork status did not modify the associations as hypothesized. *Post-hoc* analyses indicated no linear association between the DII and the IES, SPPS, PSS, or CESD. Shiftworkers in the NHANES had higher DII scores compared to day workers (1.01 vs. 0.86, p=0.01) (20). Although a larger difference was observed in the present study, the difference in mean DII values between shiftwork and non-shiftworkers was not statistically significant (0.99 vs. 0.67, respectively, p=0.32), possibly due to 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. Additionally, 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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Statement of Clinical Significance

Police officers suffer disproportionately from a variety of physical and mental health conditions when compared to the general population. Poor dietary habits may partially explain this phenomenon. Diet is a modifiable lifestyle factor that can reduce risk and burden of chronic diseases, especially among police officers.

Table 1

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

Dependent Variables	Quartile1 <−1.26	Quartile 2 <0.71	Quartile 3 <2.50	Quartile 4 ≥2.50	p-value 1 vs. 4
CRP (mg/L)[1]	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]	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-α (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_I(nmol/L-min)	126 (61–190)	203 (135–271)	118 (51–185)	149 (83–215)	0.62
Waking AUC_G(nmol/L-min)	617 (542–692)	665 (588–743)	666 (586–746)	660 (586–735)	0.40
Diurnal AUC_G(nmol/L-min)	5704 (4943–6465)	5825 (5096–6554)	5643 (4890–6397)	5766 (5034–6499)	0.89
HDL Cholesterol (mg/dL)	51 (48–54)	50 (48–53)	51 (49–54)	50 (48–53)	0.62
Triglycerides[1](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)[1]	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)	14935 (13579–16291)	14186 (12846–15527	14529 (13167–15932)	14541 (13248–15834)	0.65
Leptin[1] (pg/mL)	8819 (7074–10992)	11552 (9241–14442)	12967 (10385–16190)	9626 (7768–11929)	0.55

[1]Values were logged and LS means were back-transformed for presentation.

Adjustments: CRP = age, education, PSQI; Fibrinogen = age, race, PSQI, and SPPS score; IL-6 = rank, years of police work, and alcohol drinks per week; TNF-α = age, race, and sex; Waking AUC_I= amount of moderate to intense physical activity per week, PSQI, and PSS; Waking AUC_G= sex, amount of moderate to intense physical activity per week and IES; Diurnal AUC_G= ethnicity and IES. HDL cholesterol = sex, alcohol drinks per week, amount of moderate to intense physical activity per week, and the 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 the SPPS; Leptin = age, race, sex, and PSQI.

Abbreviations: CRP = c-reactive protein, IL= interleukin, TNF = tumor necrosis factor, AUC_I = area under the curve with respect to increase, AUC_G = area under the curves with respect to ground, CESD = Center for Epidemiologic Studies Depression Scale, SPPS = Spielberger Police Stress survey, PSS = Perceived Stress Scale, IES = Impact of Events score, SW = Shift work, PSQI = Pittsburgh Sleep Quality Index. HDL = high-density lipoprotein.

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% due to rounding. DII Quartile 1 – 4 cut-points are <−1.26, <0.71, <2.50, and ≥2.50, respectively.

Adjustments: Metabolic Syndrome = age and sex; Waist Circumference (males: ≥102 cm; females: ≥88 cm) = sex and years of police work; Blood Pressure (systolic: ≥130 mmHg; diastolic: ≥85 mmHg 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 (≥150 mg/dL) = race and sex; Glucose (≥100 mg/dL or reported treatment for diabetes) = age and sex.