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Dietary Inflammatory Index Scores Differ by Shiftwork Status: NHANES 2005–2010

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Abstract

Objective—Shiftworkers are affected by diet- and inflammation-related diseases including cardiovascular disease, diabetes, and cancer. We examined a dietary inflammatory index (DII) in relation to shiftwork from National Health and Nutrition Examination Survey data (2005–2010).

Methods—The DII was calculated using data from a 24-hour dietary recall. Shiftwork categories included day workers, evening/night shiftworkers, or rotating shiftworkers. General linear models were fit to examine the relationship between shiftwork and adjusted mean DII values.

Results—Among all shiftworkers and specifically rotating shiftworkers, higher (i.e., more pro-inflammatory) mean DII scores compared to day workers (1.01 and 1.07 vs. 0.86, both $p \leq 0.01$) were observed. Women tended to express strong evening/night shift effects.

Conclusions—More pro-inflammatory diets observed among shiftworkers may partially explain increased inflammation-related chronic disease risk observed in other studies among shiftworkers compared to their day-working counterparts.

Introduction

Shiftwork may contribute to the growing obesity and diabetes epidemics in the USA, with poor diet being one of the primary culprits (1). An increased prevalence of poor eating habits and gastrointestinal distress among shiftworkers likely contributes to diseases associated with shiftwork, such as hypertension, obesity, metabolic syndrome, cardiovascular disease (CVD), diabetes, and cancer (2–7). A recent review describing the relative paucity and inconsistencies of research findings from dietary studies focusing on shiftworkers highlights the potential etiologic role of increased consumption of calories, fats,

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protein, carbohydrates, and sweets among shiftworkers compared to non-shiftworkers (8). Western-style diets have been associated with increased chronic, systemic inflammation, whereas Mediterranean diets (i.e., high in fruit and vegetable consumption) have been associated with lower levels of systemic inflammation (9–11). Chronic inflammation is an underlying pathophysiological process contributing to the risk of metabolic syndrome (MetSyn), CVD, diabetes, and cancer (12).

A population-based dietary inflammatory index (DII) was developed to characterize an individual's diet on a continuum from maximally anti- to pro-inflammatory (13, 14). Using two different sources of dietary intake information [24-hour dietary recall (24HR) and a structured assessment instrument, the 7-day dietary recall (7DDR)], the DII predicted c-reactive protein (CRP) in the Seasonal Variation in Blood Lipids (SEASONS) study (15). Data from the Buffalo Cardio-Metabolic Occupational Police Stress (BCOPS) study indicates that higher (i.e., more pro-inflammatory) DII scores are associated with perturbations of the glucose intolerance component of MetSyn and CRP in circulation. Police officers from BCOPS working shifts tended to have elevated DII scores compared to day workers (0.99 vs. 0.67, p=0.32, manuscript submitted). We hypothesized that among a large population of workers in the National Health and Nutrition Examination Survey (NHANES) that shiftworkers would have similarly elevated DII scores compared to those individuals working only during the day.

Methods

This cross-sectional study utilized data (2005–2010) from adult (≥20 years of age) NHANES participants. Information was collected in two-year cycles using a complex, multistage, probability design to select participants from various locations and minority populations to ensure a nationally representative sample of the US population (16). Data included self-report work status, demographics, anthropometrics, lifestyle factors, and a 24HR. Other than excluding those <20 years of age, no other exclusion criteria were applied. NHANES truncated the age at 85 years for the 2005–2006 cycle and 80 years for the 2007–2008 and 2009–2010 cycles. To maintain consistency between cycles, age from each cycle was truncated to 80.

Micro and macronutrient values (known as food parameters) derived from the 24HR were assigned scores based on research summarizing findings from 1,943 articles (13). DII calculation is linked to a regionally representative world database (food consumption from 11 populations around the world) that provided a mean and standard deviation for each parameter. The “standard mean” is subtracted from the actual exposure and divided by its standard deviation. This z-score is then converted to a percentile (in order to minimize the effect of outliers or right-skewing) and centered by doubling the value and subtracting 1. The product for each food parameter and adjusted article score was calculated and then summed across all food parameters to create the overall DII score for each “participant”. The greater the DII score the more pro-inflammatory the diet; more negative values are more anti-inflammatory (13). The food parameters included in the calculation of the DII for this study included total calories; carbohydrates; protein; fat; grams of alcohol; fiber; cholesterol; saturated, monounsaturated, and polyunsaturated fatty acids; omega3 and omega6 polyunsaturated fatty acids; niacin; vitamins A, B1, B2, B6, B12, C, D, E; iron; magnesium; zinc; selenium; folic acid; beta carotene; and caffeine.

The primary exposure for this analysis was shiftwork status. Participants who were unemployed (i.e., `looking for work' or `not working at a job or business') were excluded from the analyses. Those who responded with `working at a job or business' or `with a job or business but not at work' were then asked what type of shift they typically work. Options included: 1) regular daytime, 2) evening shifts, 3) night shifts, 4) rotating shifts, or 5) another schedule (this category was removed for lack of additional information, n=714). Interviewers were instructed to continue probing to determine the exact type of shiftwork. Night (2.5%) and evening (3%) shiftworkers were combined. Duration of work in their main occupation was categorized based on a median split (i.e., ≤4 vs. >4 years). Night/evening shiftworkers and rotating shiftworkers were analyzed separately and in a combined group (`any shiftwork').

Analyses were performed using survey design procedures in SAS® (version 9.3, Cary, NC) which took into account the design effects of stratification and clustering inherent in the NHANES sampling procedure. Six-year sampling weights were created by multiplying each of the two-year sampling weights by one-third (16). Chi-square or t-tests were used to compare population characteristics by shiftwork status. Variables selected as potential confounders were identified in a series of bivariate analyses (shiftwork + covariate). Variables with a p-value of ≤0.20 were added to a `full' model. A backward elimination procedure was then used to develop final models that included all variables that were statistically significant (p<0.05) or, when removed from the model, changed the beta coefficient of the primary independent variable (i.e., shiftwork) by at least 10%. General linear models were used to compute least square (LS) means and 95% confidence intervals (95%CI) for the DII among categories of shiftwork, after adjustment for selected confounders (age, race, education, income, marital status, perceived health, amount of moderate-intense recreational physical activity per week; classification levels for each confounder are presented in Table 1). Sex and current work duration were examined as effect modifiers.

Results

Those participating in any shiftwork (n=1,445), as compared to day workers (n=6,198), were more likely to be single (30% vs. 14%, p<0.01), uninsured (29% vs. 17%, p<0.01), non-Hispanic Black (17% vs. 9%, p<0.01), to report their health as fair or poor (14% vs. 10%, p<0.01), smoke tobacco (29% vs. 20%, p<0.01), and live in a household with smokers (23% vs. 15%, p<0.01). Additionally, shiftworkers were less likely to have a college degree (16% vs. 34%, p<0.01) or an income >$65,000 (36% vs. 50%, p<0.01). Shiftworkers also were younger than day workers (mean age: 37.7±0.43 vs. 42.8±0.24 years, p<0.01), had fewer rooms in their household (6.0±0.08 vs. 6.4±0.08, p<0.01) and reported fewer hours of sleep per night (6.7±0.05 vs. 6.8+0.02, p=0.01).

Any shiftwork was associated with higher adjusted mean DII values compared to day workers (1.01 vs. 0.86, p ≤0.01). When shiftworkers were separated by subgroup, rotating shiftworkers had higher adjusted mean DII values compared to day workers (1.07 vs. 0.86, p<0.01), whereas no statistically significant difference in the DII was observed between evening/night shiftworkers and day workers (Table 2). Crude DII values were substantially lower among males compared to females (0.49 vs. 1.23, p<0.01) and therefore analyses were stratified by gender. Among men, rotating shiftworkers had higher adjusted mean DII values compared to day workers (0.93 vs. 0.63, p<0.01). Among women, evening/night shiftworkers had higher mean DII values compared to day workers (1.48 vs. 1.17, p=0.01) (Table 2). A difference in mean DII scores was observed among workers stratified by the median duration of current occupation (0.69 vs. 0.90, respectively, p<0.01), although this effect did not modify the relationship between shiftwork and the DII (data not presented). Mean DII values for each potential confounder included in the main analysis are presented in a supplemental table (see Table, Supplemental Digital Content 1, which shows the mean DII by categories of all confounders).

Discussion

We compared the inflammatory potential of diet in NHANES, a nationally representative sample of shiftworkers and day workers using a novel DII. The mean DII value in this NHANES population was 0.87±1.08; similar to other populations (i.e., SEASONS study [0.84±1.99] (15)), but higher (i.e., more pro-inflammatory) than a working-only population of police officers (i.e., BCOPS [0.59±2.55], manuscript submitted). Findings from this study indicate that shiftworkers have more pro-inflammatory diets than day workers; though, it is not clear what such a magnitude of difference actually means biologically or how it would translate into health outcomes. However, it probably is not trivial as this difference represents about 10% of the interquartile range of possible DII values (13). Inflammation plays an etiologic role in the development of several chronic disorders associated with shiftwork, including MetSyn, cancer, CVD, stroke and diabetes (17–19). Associations between the DII and health outcomes in future longitudinal studies will provide more definitive inferences regarding the relationship between the DII and adverse health outcomes. Results from this study show that shiftworkers' diets have greater pro-inflammatory potential compared to their day-working counterparts.

Stress, fatigue, sleep loss, and familial disruption that occur among shiftworkers likely contribute to poor dietary habits, potentially increasing the inflammatory nature of their diet. Shiftworkers snack more often than day workers (20). They may eat a meal with their family prior to work, and another meal during work, which could result in overeating (8). Healthy and nutritious food options may not be available during night work hours (8). Nighttime consumption of food may disrupt circadian processes, which could affect appetite and metabolism (21). This is supported by studies among shiftworkers indicating abnormal levels or dysregulated circadian rhythms of several hormones involved in the regulation of appetite or metabolism, including leptin and ghrelin (19, 22). Night workers have more gastrointestinal symptoms and antacid use relative to day workers (3, 23), as well as increased risks for central adiposity, ulcers, hypertension, and coronary heart disease (2, 4, 24, 25). However, the relative contributions of diet to these outcomes have not been fully characterized.

This study had several noteworthy strengths, limitations, and uncertainties. Although the DII difference between shiftworkers and day workers in the current analysis was similar to that observed in the BCOPS study (manuscript submitted), statistical significance in this study was achieved, most likely due to precision conferred by its larger sample size. Another strength is the representation of minorities in proportion to their representation in the general US population. Limitations include the use of self-report questions for shiftwork ascertainment, as opposed to the use of electronic payroll records (e.g., BCOPS) (26, 27). However, we identified a shiftwork prevalence of 19%, which is similar to other reports (28). Recently, a similar definition of shiftwork was used to examine the relationship between shiftwork and prostate-specific antigen using NHANES data (29), or depression using the Korean NHANES (30). The use of `years at current occupation' to quantify shiftwork most likely led to misclassification as individuals may not have spent the entire duration on one specific shift type. It is unclear why DII values among men on rotating shifts were higher compared to day workers, whereas DII values among women working night/evening shifts were elevated relative to day workers. Given the cross-sectional nature of this study and relative paucity of shiftwork-related information, it was not possible to determine whether the differences reflect dietary habits that may be elicited by different shift schedules, whether these differences are more representative of sex-related differences in dietary patterns, or whether they relate to job-specific or occupational differences among shiftworking men and women. Lastly, only one 24HR was utilized to calculate the DII. Estimates of dietary intake are subject to day-to-day variability, so a single day of information would provide a relatively imprecise estimate of usual intake that adds to overall variability and, thereby, imprecision (31).

Shiftworkers suffer from increased risk of numerous chronic disorders (17). This most likely occurs through a complex causal model involving numerous behavioral, psychosocial, and biological perturbations. Inflammatory diets represent a target for behavioral interventions to reduce the health impacts of shiftwork (1). The DII may serve as a useful instrument to evaluate the impacts of diet and dietary interventions among shiftworkers. However, chronic disease risk among shiftworking populations is most likely multi-faceted. Interventions to reduce chronic disease risk among shiftworkers should incorporate several important lifestyle changes (e.g., healthy diet, physical activity, proper sleep and light exposure). Dietary habits and barriers are poorly understood among shiftworkers (8) and future research should elaborate on the interplay between diet and shiftwork as they relate to chronic disease prevention in order to develop effective lifestyle inventions among shiftworkers.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Table 1

Population Characteristics by Work Status

Characteristic	Day Workers (n=6198)	Shiftworkers (n=1445)	p-value[1]
Sex			
Male	3277 (53%)	766 (54%)	
Female	2921 (47%)	679 (46%)	0.64
Race			
Non-Hispanic White	2963 (72%)	555 (61%)	
Non-Hispanic Black	1131 (9%)	388 (17%)	
Mexican American	1260 (9%)	280 (9%)	
Other	844 (10%)	222 (13%)	<0.01
Military			
Yes	557 (9%)	131 (10%)	
No	5641 (91%)	1314 (90%)	0.56
Education			
<High School	1354 (14%)	348 (17%)	
Completed High School	1394 (22%)	384 (28%)	
Some College	1766 (30%)	526 (39%)	
≥College Degree	1684 (34%)	187 (16%)	<0.01
Marital Status			
Married/Living with Partner	4191 (70%)	754 (54%)	
Widowed/Divorced/Separated	965 (14%)	261 (16%)	
Never Married	1042 (16%)	430 (30%)	<0.01
Perceived Health			
Excellent	1085 (20%)	217 (17%)	
Very Good	1944 (37%)	415 (33%)	
Good	2215 (33%)	561 (37%)	
Fair or Poor	954 (10%)	252 (14%)	<0.01
Health Insurance			
Yes	4686 (83%)	946 (71%)	
No	1511 (17%)	497 (29%)	<0.01
Income			
<$20,000	932 (10%)	326 (18%)	
$20,000 – $34,999	1108 (13%)	303 (17%)	
$35,000 – $64,999	1686 (27%)	418 (29%)	
>$65,000	2472 (50%)	398 (36%)	<0.01
Smoking Family Member			
Yes	927 (15%)	318 (23%)	
No	5270 (85%)	1127 (77%)	<0.01
Smoking Status			
Current	1289 (20%)	401 (29%)	
Former	1349 (27%)	236 (17%)	

Characteristic	Day Workers (n=6198)	Shiftworkers (n=1445)	p-value[1]
Never	3558 (57%)	808 (54%)	<0.01
Age	42.8 ± 0.24	37.7 ± 0.43	<0.01
Number of Household Rooms	6.4 ± 0.08	6.0 ± 0.08	<0.01
Sleep Duration (Hours)	6.8 ± 0.02	6.7 ± 0.05	0.01
Body Mass Index	28.5 ± 0.13	28.7 ± 0.23	0.33
Drinks per Week	0.20 ± 0.01	0.31 ± 0.07	0.14
Moderate-Vigorous PA Minutes [3]	166.5 ± 5.6	179.7 ± 12.6	0.29

Column percentages may not equal 100% due to rounding. Stratum numbers may not equal column totals due to missing data. All categorical variable p-values based on chi-square tests and all continuous p-values based on general linear models. Shiftworkers represent combined evening/night and rotating shiftworkers.

[1] p-values compare day workers to shiftworkers.

[3] Represents minutes per week.

Table 2

Adjusted Mean Dietary Inflammatory Index Scores (95% Confidence Interval) by Work Category Stratified by Sex[1]

Work Category	All Subjects (n= 7,643)	p-value	Males (n= 4,043)	p-value	Females (n= 3,600)	p-value
Day Shifts (n= 6,198)	0.86 (0.79–0.94)	--	0.63 (0.54–0.73)	--	1.17 (1.08–1.26)	--
Evening/Night Shifts (n=790)	0.96 (0.80–1.13)	0.26	0.62 (0.39–0.85)	0.91	**1.48 (1.25–1.71)**	**0.01**
Rotating Shifts (n=655)	**1.07 (0.92–1.22)**	**<0.01**	**0.93 (0.72–1.13)**	**<0.01**	1.25 (1.05–1.44)	0.42
Any Shiftwork (n= 1,445)[2]	**1.01 (0.89–1.13)**	**0.01**	0.75 (0.58–0.93)	0.17	**1.36 (1.22–1.51)**	**0.01**

[1] DII scores have not been found to exceed the range of −10 to 10. Values >0 are pro-inflammatory and those <0 are anti-inflammatory.

[2] Represents combined evening/night and rotating shift categories. All models adjusted for age, race, education, income, marital status, perceived health, and moderate-intense recreational physical activity minutes per week.