

Original Article

Separate and Joint Associations of Shift Work and Sleep Quality with Lipids



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ABSTRACT

Background: Shift work and/or sleep quality may affect health. We investigated whether shift work and sleep quality, separately and jointly, were associated with abnormal levels of triglycerides, total cholesterol (TC), and low- and high-density lipoprotein cholesterol in 360 police officers (27.5% women). **Methods:** Triglycerides, TC, and high-density lipoprotein were analyzed on the Abbott Architect; low-density lipoprotein was calculated. Shift work was assessed using City of Buffalo payroll work history records. Sleep quality (good, ≤ 5 ; intermediate, 6–8; poor, ≥ 9) was assessed using the Pittsburgh Sleep Quality Index questionnaire. A shift work + sleep quality variable was created: day plus good sleep; day plus poor sleep; afternoon/night plus good; and poor sleep quality. Mean values of lipid biomarkers were compared across categories of the exposures using analysis of variance/analysis of covariance.

Results: Shift work was not significantly associated with lipids. However, as sleep quality worsened, mean levels of triglycerides and TC gradually increased but only among female officers (age- and race-adjusted $p = 0.013$ and 0.030 , respectively). Age significantly modified the association between sleep quality and TC. Among officers ≥ 40 years old, those reporting poor sleep quality had a significantly higher mean level of TC (202.9 ± 3.7 mg/dL) compared with those reporting good sleep quality (190.6 ± 4.0 mg/dL) (gender- and race-adjusted $p = 0.010$). Female officers who worked the day shift and also reported good sleep quality had the lowest mean level of TC compared with women in the other three categories ($p = 0.014$).

Conclusion: Sleep quality and its combined influence with shift work may play a role in the alteration of some lipid measures.

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1. Introduction

Cardiovascular disease (CVD) is the leading cause of morbidity and mortality in the United States and in other countries [1]. CVD risk factors include elevated levels of certain lipid biomarkers such as triglycerides and low-density lipoprotein (LDL) cholesterol, low levels of high-density lipoprotein (HDL) cholesterol [2–6], and exposure to shift work [7,8]. Abnormal levels of certain lipids are relatively common among Americans. Using the National Health

and Nutrition Examination Survey data, Carroll and colleagues [9] found that an estimated 12.9% of US adults, aged 20 years and older (11.1% of men and 14.4% of women), had a high level of total cholesterol (TC) in 2011–2012, and this percentage had not changed since 2009–2010. Approximately 17% of adults (about 25% of men and < 10% of women) had low HDL cholesterol during the same period.

Police officers have a high prevalence of CVD and its associated risk factors such as hypertension, hyperlipidemia, and metabolic

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syndrome [10]. Their occupational exposures may contribute to these adverse health conditions. Police officers are exposed to many psychological and organizational stressors such as violence, traumatic events, and shift schedules [10], and perhaps more so than many other occupational groups [11].

Shift work is one of the occupational factors that has been shown to be associated with elevated levels of triglycerides and TC [8,12–16]. In the epidemiologic literature, the association between sleep quality and lipid levels has shown mixed results [17–20]. Using data from the Coronary Artery Risk Development in Young Adults Sleep Study (2003–2005), Petrov and colleagues [17] did not find a significant association between self-reported poor sleep quality and 10-year changes in lipid levels. In addition, among a group of 143 law enforcement officers, sleep quality was not significantly related to any of the individual components of metabolic syndrome, including elevated triglycerides and reduced HDL cholesterol [18]. However, among 3,435 Taiwanese adults, low HDL cholesterol was an independent predictor of having a higher global sleep score (i.e., being a poor sleeper), as measured by the Pittsburgh Sleep Quality Index (PSQI) [19]. Moreover, a study conducted in Republic of Korea showed that individuals reporting poor sleep quality had a higher prevalence of elevated triglycerides and low HDL cholesterol [20].

Not surprisingly, night shift work is generally associated with poor sleep quality [21,22]. We could not find any evidence of the combined adverse impact of shift work and poor sleep quality on lipid biomarkers in the epidemiological literature. Therefore, this study aims to evaluate the separate and joint associations of shift work and sleep quality with four lipid biomarkers, triglycerides, TC, and HDL cholesterol and LDL cholesterol, among police officers. Even though this topic could have been studied on many different groups, we used police officers because (1) police officers experience a high degree of stress in their jobs and, therefore, may be more likely to reveal adverse health effects of stress and (2) they are an understudied occupational group. In addition, this study is unique in that the influence of both shift work and poor sleep quality is jointly being examined in relation to their potential adverse effects on lipids. We hypothesized that officers who worked the afternoon/night shift and reported poor sleep quality would have higher mean levels of triglycerides, TC, and LDL cholesterol and lower mean levels of HDL cholesterol. This association may differ by age, gender, and/or use of lipid-lowering medications. At different ages, sleep needs and metabolic function may vary. It is possible that, at younger ages, lipid metabolism may be less susceptible to the effects of an irregular shift schedule or poor sleep quality. Different lifestyle habits or hormonal reactions among men and women may strengthen or attenuate the association between the exposures and lipids. In addition, use of lipid-lowering medications would most likely obscure any association of shift work or sleep quality with lipids. Therefore, a secondary aim is to investigate whether effect modification by age, gender, and use of lipid-lowering medications exists in these associations.

2. Materials and methods

2.1. Study design and participants

Participants in this cross-sectional study were police officers employed at the Buffalo Police Department, New York. From June 2004 through October 2009, 464 active-duty and retired police officers (from an estimated 710 officers in 2004) were recruited and examined in the Buffalo Cardio-metabolic Occupational Police Stress (BCOPS) study. The BCOPS study was undertaken to investigate associations between work-related stressors and health outcomes including subclinical measures of CVD [23]. Female

officers who were pregnant at the time of examination were excluded. The officers reviewed and signed informed consent forms prior to the examinations. The data were collected at the Center for Health Research, School of Public Health and Health Professions, University at Buffalo, State University of New York [23]. The Institutional Review Boards at the University at Buffalo and the National Institute for Occupational Safety and Health approved the study. From the original sample of 464, officers were excluded if they had retired by 2009 or if information was not collected on shift work, sleep quality, or any of the lipid measures ($n = 104$). Analysis for this study was conducted on 360 police officers, 99 women and 261 men.

2.2. Shift work

Electronic work history data from 1994 to 2010 were available from the City of Buffalo payroll records. The database contained information regarding the daily activities of each officer and included the start and end time of work, type of activity (i.e., regular work, overtime work, and court appearances), type of leave (i.e., weekend, vacation, work-related injuries, and other types of sick leave), and number of hours worked on each activity. The time the participants started their regular scheduled shift was used to classify each record into one of the following three shifts: day shift, if the start time of the record was between 4:00 AM and 11:59 AM; afternoon shift, if the start time was between 12:00 PM and 7:59 PM; and night shift, if the start time was between 8:00 PM and 3:59 AM. The majority (> 90%) of officers who were classified as day shift workers began work at 7:00 AM or 8:00 AM. An officer's dominant shift was defined as the shift on which he/she worked the highest percentage of hours. For example, the dominant shift would be night shift for an officer who worked 10% on the day shift, 5% on the afternoon shift, and 85% on the night shift. We used data on the dominant shift worked during the previous year (from time of blood collection) since this length of time would be sufficient to study associations with lipids.

2.3. Sleep quality

Sleep quality was assessed using the PSQI questionnaire [24]. Sleep quality was measured from 19 self-rated items that assessed various sleep quality-related factors over the previous month. These 19 items were grouped into seven components that include subjective sleep quality, sleep latency (i.e., time taken to fall asleep), sleep duration, habitual sleep efficiency (i.e., number of hours slept/number of hours spent in bed), sleep disturbances, use of sleep medications, and daytime dysfunction. Each component was scored by summing the scores of relevant items. Each item was weighted equally on a 0–3 scale. A global PSQI score was derived by summing up the scores of the seven components, with a possible range of 0–21; a global score of ≤ 5 indicated good sleep quality [24]. The PSQI global score provides a single overall assessment of sleep quality, allows direct comparisons among groups, and identifies groups that differ in the quality of sleep. Studies have shown that the PSQI has high internal homogeneity, reliability, and validity [24,25].

2.4. Lipids

All officers were required to fast for at least 12 hours before blood specimens were taken. Serum specimens were used for all lipid measures. TC, HDL cholesterol, and triglycerides were analyzed on the Abbott Architect (Abbott Diagnostics, Abbott Park, IL, USA). LDL cholesterol was calculated from measurements obtained for TC, HDL cholesterol, and triglycerides using the following formula: $LDL = TC - HDL - \text{triglycerides}/5$ (mg/dL).

2.5. Covariates

Officers provided information on demographic characteristics (age, gender, race/ethnicity, years of service, police rank, educational level, and marital status), lifestyle behaviors (alcohol consumption, smoking status, and physical activity), and medical history via self- and interviewer-administered questionnaires. Anthropometric measurements were conducted by trained technicians. Body mass index (BMI) was calculated as weight (in kilograms) divided by height (in meters) squared. Data on physical activity during the previous 7 days were obtained with the Seven-Day Physical Activity Recall questionnaire used in the Stanford Five-City Project [26].

2.6. Statistical analysis

In order to study the joint effects of shift work and sleep quality, we first created a new variable called shift work + sleep quality. Afternoon and night shifts were combined due to the small number of officers on the night shift. The global PSQI scores for sleep quality were divided into three categories: good (≤ 5), intermediate (6–8), and poor (≥ 9) sleep quality. The joint variable was created with four categories: (1) day plus good (≤ 5) sleep quality; (2) day plus poor (> 5) sleep quality; (3) afternoon/night plus good sleep quality; and (4) afternoon/night plus poor sleep quality. Simple descriptive measures were calculated for all variables. Owing to the skewed distribution of triglycerides, this variable was log-transformed prior to analysis, and the results were back-transformed and reported as means [95% confidence interval (CI)]. Associations of all covariates with the three exposure variables (shift work, sleep quality, and shift work + sleep quality) and the four lipid biomarkers (triglycerides, TC, HDL, and LDL) were examined using the Pearson's correlation coefficient, chi-square test of independence, and analysis of variance. Analysis of covariance was used to obtain mean levels of the lipid biomarkers across categories of the three exposure variables. The p values for the association between sleep quality and lipids were obtained from linear regression; p values for the other associations were obtained from analysis of covariance. Effect modification was assessed for age, gender, and use of lipid-lowering medications. Confounders were selected based on their significant associations with both independent and dependent variables, and/or if these variables were shown to be confounders in previous studies. Confounders included age, gender, and race/ethnicity. Analyses were conducted in SAS version 9.3 [27].

3. Results

Descriptive statistics of demographic, lifestyle, and other characteristics are presented in Table 1. The mean (\pm standard deviation) age of all 360 police officers was 41.2 ± 6.6 years (range 27–66 years). The majority of the officers were white or Hispanic (78.6%) and had a rank of patrol officer (71.9%); women officers represented 27.5% of the entire sample. The mean level of BMI was significantly higher in male than in female officers. Compared with women, men had significantly higher mean levels of triglycerides, TC, and LDL cholesterol, and significantly lower mean levels of HDL cholesterol. Based on our methods for shift work classification, officers placed in any of the three shifts worked from 50% to 100% of the time on that shift. However, the majority of officers worked on their scheduled shifts over 90% of the time: 91.3% of day shift officers, 86% of afternoon shift officers, and 80% of night shift officers. Shift work was significantly associated with gender ($p < 0.001$). For example, a higher percentage of women worked the day shift,

whereas a higher percentage of men worked the night shift. Sleep quality was not significantly associated with gender.

Table 2 shows the unadjusted associations between selected characteristics and the four lipid biomarkers, stratified by gender. Age was significantly associated with LDL cholesterol among women. In addition, among women, BMI was strongly and positively correlated with triglycerides, TC, and LDL cholesterol, and negatively correlated with HDL cholesterol. Race/ethnicity was significantly associated with triglycerides among both women and men; African American officers had significantly lower mean values of triglycerides compared with white and Hispanic officers. Among men (but not among women), current and former smokers had significantly higher mean levels of triglycerides compared with never smokers. Female officers who were diagnosed with hypertension had significantly higher mean levels of TC and LDL cholesterol compared with those without hypertension.

We presented all of the main associations stratified by gender. The gender-stratified associations between shift work and lipids are shown in Table 3. Shift work was not significantly associated with any of the lipid biomarkers, before or after adjustment for age and race/ethnicity.

The associations between sleep quality and lipids, stratified by gender, are shown in Table 4. Among women only, sleep quality was significantly associated with triglycerides and TC before and after adjustment, but not with any other lipid biomarker. As the quality of sleep decreased, mean levels of triglycerides and TC showed a monotonic increase among female officers (age- and race-adjusted $p = 0.013$ and 0.030 , respectively). There were no significant associations between sleep quality and any of the lipid measures among men.

Use of lipid-lowering medications did not significantly modify the associations of shift work or sleep quality with any of the lipid measures (data not shown). However, age significantly modified the association between sleep quality and TC (interaction $p = 0.015$). In Fig. 1, we show the association between sleep quality and TC stratified by age (< 40 years vs. ≥ 40 years). Sleep quality was not significantly associated with TC among younger officers (i.e., < 40 years of age). However, among officers ≥ 40 years old, those reporting poor sleep quality had significantly higher mean levels of TC (202.9 ± 3.7 mg/dL) compared with those reporting good sleep quality (190.6 ± 4.0 mg/dL), after adjustment for gender and race/ethnicity ($p = 0.010$).

The gender-stratified associations between shift work + sleep quality and the four lipid biomarkers are presented in Table 5. Shift work + sleep quality was significantly associated with TC in women only. Female officers who worked the day shift and also reported good sleep quality had the lowest mean level of TC (174.7 ± 6.2 mg/dL) compared with the other three groups, after adjustment for age and race/ethnicity ($p = 0.014$).

4. Discussion

In this group of law enforcement officers, our primary goal was to determine whether shift work, sleep quality, and the combination of shift work and sleep quality were associated with triglycerides, TC, HDL cholesterol, and LDL cholesterol.

4.1. Shift work, sleep quality, and triglycerides

The results of our study showed that shift work was not significantly associated with blood levels of triglycerides. However, among female officers only, sleep quality was inversely associated with mean levels of triglycerides.

Our findings of no significant association between shift work and triglycerides are not supported by most studies. Cross-sectional

Table 1
Demographic and other characteristics of the study participants by gender; BCOPS 2004–2009

Characteristics	All (n = 360), mean ± SD	Women (n = 99), mean ± SD	Men (n = 261), mean ± SD	p
Age (27–66 y)	41.2 ± 6.6	41.0 ± 5.8	41.3 ± 6.9	0.740
Years of service	14.5 ± 6.8	13.6 ± 6.4	14.8 ± 7.0	0.153
BMI (kg/m ²)	29.2 ± 4.7	26.0 ± 4.8	30.4 ± 4.1	< 0.0001
Alcohol (drinks/wk)	5.2 ± 8.3	3.3 ± 4.5	5.9 ± 9.3	0.001
Sleep duration (h/24 h)	6.1 ± 1.2	6.1 ± 1.2	6.1 ± 1.2	0.959
Triglycerides (mg/dL)	132.7 (122.0–143.4)	76.9 (67.2–86.7)	153.8 (140.4–167.3)	< 0.0001
Total cholesterol (mg/dL)	202.3 ± 37.8	193.9 ± 36.5	205.4 ± 37.9	0.010
LDL cholesterol (mg/dL)	129.4 ± 34.0	120.4 ± 31.8	132.9 ± 34.2	0.002
HDL cholesterol (mg/dL)	46.6 ± 14.7	58.2 ± 15.2	42.2 ± 11.9	< 0.0001
Education				0.054
≤ HS/GED	37 (10.3)	4 (4.0)	33 (12.7)	
< 4 y college	205 (57.1)	60 (60.6)	145 (55.8)	
≥ 4 y college	117 (32.6)	35 (35.4)	82 (31.5)	
Race/ethnicity				0.050
White/Hispanic	279 (78.6)	71 (71.7)	208 (81.3)	
African American	76 (21.4)	8 (28.3)	48 (18.8)	
Rank				0.115
Patrol officer	259 (71.9)	79 (79.8)	180 (69.0)	
Sergeant/lieutenant	51 (14.2)	11 (11.1)	40 (15.3)	
Captain/detective/other	50 (13.9)	9 (9.1)	41 (15.7)	
Smoking status				< 0.001
Current	61 (17.0)	25 (25.8)	36 (13.8)	
Former	82 (22.9)	30 (30.9)	52 (19.9)	
Never	215 (60.1)	42 (43.3)	173 (66.3)	
Shift work				< 0.0001
Day	172 (47.8)	76 (76.8)	96 (36.8)	
Afternoon	99 (27.5)	8 (8.1)	91 (34.9)	
Night	89 (24.7)	15 (15.2)	74 (28.4)	
Sleep quality				0.713
Good (≤ 5)	162 (45.0)	43 (43.4)	119 (45.6)	
Poor (> 5)	198 (55.0)	56 (56.6)	142 (54.4)	
Shift work + sleep quality				< 0.0001
Day + good	76 (21.1)	31 (31.3)	45 (17.2)	
Day + poor	65 (18.1)	37 (37.4)	28 (10.7)	
Afternoon/night + good	86 (23.9)	12 (12.1)	74 (28.4)	
Afternoon/night + poor	133 (36.9)	19 (19.2)	114 (43.7)	

The p values are for differences between women and men.

For continuous variables, p values were obtained from t tests.

For categorical variables, p values were obtained from chi-square or Fisher's exact tests.

Shift work refers to the dominant shift in the past 1 year.

BCOPS, Buffalo Cardio-metabolic Occupational Police Stress; BMI, body mass index; GED, General Education Development; HDL, high-density lipoprotein; HS, High School; LDL, low-density lipoprotein; SD, standard deviation.

and prospective studies show significant associations between shift work and elevated levels of triglycerides. Among factory workers in Malaysia, the prevalence of elevated levels of triglycerides (42.1%) was significantly higher among shift workers (who worked rotating shifts including night shifts) than among day workers [28]. In another cross-sectional study conducted in France, male rotating shift workers (i.e., those who were regularly scheduled on 3 shifts) had significantly higher levels of serum triglyceride than fixed day workers, independent of BMI, age, smoking, and energy and alcohol intake [16]. Using the methods of the Third Report of the National Cholesterol Education Program Expert Panel on Detection, Evaluation and Treatment of High Blood Cholesterol in Adults and the International Diabetes Federation, rotating shift workers in the healthcare industry were more likely to have high plasma triglycerides than daytime workers [29]. In yet another cross-sectional study, results showed that triglycerides were significantly increased in rotating shift workers, and the proportion of individuals displaying triglyceride values above normal range (≥ 150 mg/dL) was 1.5-fold higher in this group than in the group of day workers [14]. Results from two studies conducted by Karlsson and colleagues [30,31] showed that components of metabolic syndrome, including significantly higher levels of triglycerides, were observed in rotating male shift workers compared with day workers. One longitudinal study also reported that shift work was a

risk factor for increased levels of triglycerides [12]. However, one retrospective cohort study conducted on Iranian workers reported no significant relationship between shift work and triglycerides [32].

Only one study was identified that investigated the association between sleep quality and triglycerides in a healthy population. This cross-sectional study, conducted among adults in China who were free of CVD and diabetes, found that self-reported poor sleep quality was associated with slightly higher mean levels of triglycerides (in addition to inflammatory biomarkers) compared with good sleep quality [33].

4.2. Shift work, sleep quality, and TC

Our results showed that shift work alone was not significantly associated with TC. However, among female officers only, mean levels of TC increased as sleep quality worsened. In addition, mean levels of TC were significantly lower in female officers who worked the day shift and also reported good sleep quality compared with those in the other three groups.

Our results between shift work and TC were not supported by several other studies. All the studies that we reviewed reported higher levels of cholesterol among shift workers. In a longitudinal study of 1,529 male blue-collar workers in Japan, Morikawa and

Table 2

Associations of selected characteristics with lipid biomarkers, stratified by gender; BCOPS 2004–2009

	Triglycerides	Total cholesterol	HDL	LDL
Women (n = 99)				
Age (y)	−0.060, 0.556	0.193, 0.056	0.017, 0.870	0.222, 0.027
Years of service	−0.050, 0.620	0.061, 0.549	0.004, 0.965	0.068, 0.502
BMI (kg/m ²)	0.294, 0.003	0.215, 0.033	−0.314, 0.002	0.317, 0.001
Alcohol (drinks/wk)	0.081, 0.425	0.060, 0.559	0.082, 0.424	0.010, 0.924
Physical activity	−0.049, 0.632	0.263, 0.009	0.172, 0.088	0.220, 0.029
Race/ethnicity				
White/Hispanic	71.3 (63.2–80.6)	198.0 ± 37.8	60.6 ± 15.5	120.6 ± 33.0
African American	55.0 (45.3–66.8)	183.6 ± 31.0	51.9 ± 12.9	119.8 ± 28.9
<i>p</i>	0.027	0.077	0.010	0.917
Smoking status				
Current	75.9 (61.5–93.8)	187.2 ± 28.3	55.0 ± 15.1	115.9 ± 24.7
Former	63.1 (52.0–76.5)	193.6 ± 36.9	59.4 ± 15.7	119.4 ± 32.7
Never	63.0 (53.6–74.2)	198.0 ± 41.2	59.1 ± 15.4	123.5 ± 35.6
<i>p</i>	0.329	0.517	0.502	0.636
BMI (kg/m²)				
Normal (< 25.0)	59.2 (51.1–68.6)	188.0 ± 28.3	62.0 ± 15.4	112.1 ± 23.7
Overweight (≥ 25)	74.1 (64.0–85.7)	199.7 ± 42.5	54.4 ± 14.2	128.4 ± 36.5
<i>p</i>	0.034	0.112	0.012	0.010
Hypertension				
Yes	80.7 (62.2–104.6)	213.6 ± 42.7	59.2 ± 16.3	134.9 ± 41.8
No	63.8 (56.9–71.5)	190.1 ± 34.1	58.0 ± 15.1	117.5 ± 28.9
<i>p</i>	0.105	0.018	0.775	0.044
Men (n = 261)				
Age (y)	0.046, 0.458	0.051, 0.416	0.058, 0.353	0.024, 0.696
Years of service	0.078, 0.211	0.070, 0.259	0.051, 0.412	0.028, 0.655
BMI (kg/m ²)	0.202, 0.001	0.045, 0.465	−0.125, 0.044	0.002, 0.978
Alcohol (drinks/wk)	0.059, 0.341	0.152, 0.014	0.204, 0.001	0.035, 0.579
Physical activity	−0.086, 0.167	0.040, 0.517	0.035, 0.574	0.070, 0.262
Race/ethnicity				
White/Hispanic	132.7 (121.7–144.6)	209.0 ± 37.1	42.5 ± 12.0	134.9 ± 33.7
African American	86.9 (72.6–103.9)	187.8 ± 36.2	41.4 ± 11.5	123.6 ± 34.5
<i>p</i>	<0.0001	<0.001	0.573	0.038
Smoking status				
Current	149.3 (120.7–184.6)	213.7 ± 37.5	42.8 ± 11.8	133.2 ± 31.0
Former	145.4 (121.8–173.5)	204.3 ± 32.7	42.2 ± 11.1	127.9 ± 31.2
Never	114.1 (103.6–125.7)	204.1 ± 39.4	42.0 ± 12.1	134.3 ± 35.7
<i>p</i>	0.013	0.375	0.937	0.496
BMI (kg/m²)				
Normal (< 25.0)	80.9 (59.9–109.3)	190.2 ± 28.3	46.9 ± 12.4	123.2 ± 28.0
Overweight (≥ 25)	128.3 (118.2–139.2)	206.6 ± 38.4	41.8 ± 11.8	133.6 ± 34.6
<i>p</i>	0.004	0.077	0.079	0.214
Hypertension				
Yes	141.5 (120.5–166.2)	200.2 ± 37.2	40.3 ± 13.1	125.4 ± 34.1
No	119.1 (108.7–130.6)	207.1 ± 38.1	42.8 ± 11.4	135.3 ± 34.0
<i>p</i>	0.069	0.208	0.150	0.044

Results for continuous variables are Pearson's correlation coefficients and *p* values.Results for categorical variables are means (95% CI) for triglycerides and means ± SD for all other lipid biomarkers. The *p* values are for any difference between the means, obtained from ANOVA.

Results for triglycerides were first log-transformed then back-transformed for reporting.

ANOVA, analysis of variance; BCOPS, Buffalo Cardio-metabolic Occupational Police Stress; BMI, body mass index; CI, confidence interval; HDL, high-density lipoprotein; LDL, low-density lipoprotein; SD, standard deviation.

colleagues [15] reported that shift workers had a generally higher increase in TC compared with day workers, even though the differences were not statistically significant. In a 14-year prospective cohort study conducted in Japanese day workers ($n = 4,079$) and alternating shift workers ($n = 2,807$), alternating shift work had a significant adverse effect on serum TC level [13]. In yet another longitudinal study, Italian street cleaners and garbage workers who had always worked night shifts had significantly higher serum TC than day workers [12].

Among factory workers in Malaysia, the prevalence of elevated levels of cholesterol (47.4%) was significantly higher among shift workers than among day workers [28]. In another cross-sectional study conducted on men in France, rotating shift workers had significantly higher levels of serum triglycerides than day workers, independent of BMI, age, smoking, and energy and alcohol intake, but no association was observed with TC and HDL cholesterol levels [16]. In a large ($n = 27,485$) cross-sectional study, TC levels were higher in all shift-working (by self-report) women except the youngest age group [30].

Our results with respect to sleep quality were consistent with those of one study. Haseli-Mashhadi and colleagues [33] found

significantly higher mean levels of TC among those who reported average or poor sleep quality compared with those who reported good sleep quality.

4.3. Shift work, sleep quality, and HDL cholesterol

Female officers on the afternoon shift tended to have a higher mean level of HDL cholesterol compared with those on the day and night shifts, but the association was not statistically significant. The lack of a significant association may have been due in part to the relatively small sample of women. In addition, sleep quality was not significantly associated with HDL cholesterol. The results in the epidemiologic literature are mixed. In a 1-year cohort study conducted by van Amelsvoort and colleagues [34], a significant increase in HDL cholesterol level was found in shift workers. In their study, shift work was self-reported and was defined as working in an alternating work schedule, including nights. Another study found that shift workers (who rotated shifts) in the healthcare industry were more likely to have metabolic risk factors, such as low HDL cholesterol and high plasma triglycerides, than daytime workers [29]. Two cross-sectional studies by Karlsson and

Table 3
Mean values of lipid biomarkers by levels of shift work, stratified by gender; BCOPS 2004–2009

	Day	Afternoon	Night	<i>p</i>
Women	<i>n</i> = 68	<i>n</i> = 17	<i>n</i> = 14	
Triglycerides				
Model 1	63.5 (55.6–72.6)	71.0 (54.4–92.6)	75.0 (55.9–100.7)	0.551
Model 2	61.0 (53.2–69.9)	65.1 (49.5–85.7)	69.5 (51.6–93.5)	0.718
Total cholesterol				
Model 1	189.8 ± 4.5	206.0 ± 9.0	199.5 ± 10.0	0.276
Model 2	187.7 ± 4.7	201.6 ± 9.4	195.6 ± 10.2	0.394
HDL cholesterol				
Model 1	56.6 ± 1.9	66.5 ± 3.8	55.6 ± 4.2	0.055
Model 2	55.3 ± 1.9	63.7 ± 3.9	53.2 ± 4.2	0.084
LDL cholesterol				
Model 1	117.8 ± 3.9	124.5 ± 7.9	127.5 ± 8.7	0.550
Model 2	117.9 ± 4.1	124.7 ± 8.3	127.7 ± 9.0	0.555
Men	<i>n</i> = 73	<i>n</i> = 112	<i>n</i> = 76	
Triglycerides				
Model 1	120.0 (102.3–140.9)	124.5 (110.0–140.8)	128.2 (110.1–149.2)	0.851
Model 2	110.2 (93.7–129.6)	104.3 (90.6–120.0)	108.3 (91.9–127.8)	0.845
Total cholesterol				
Model 1	207.6 ± 4.7	204.9 ± 3.6	204.2 ± 4.5	0.868
Model 2	202.9 ± 4.8	196.6 ± 4.2	195.4 ± 4.9	0.483
HDL cholesterol				
Model 1	44.1 ± 1.5	41.2 ± 1.1	41.6 ± 1.4	0.279
Model 2	44.0 ± 1.5	40.8 ± 1.3	41.2 ± 1.6	0.243
LDL cholesterol				
Model 1	133.1 ± 4.2	133.5 ± 3.3	131.8 ± 4.0	0.942
Model 2	130.3 ± 4.4	129.8 ± 3.8	127.1 ± 4.5	0.842

Shift work refers to the dominant shift in the past 1 year.

The *p* values were obtained from ANCOVA.

Results for triglycerides were first log-transformed then back-transformed for reporting. Results for triglycerides are means (95% CI); all other results are means ± SE.

Model 1: adjusted for age.

Model 2: adjusted for age and race/ethnicity.

Interaction by gender in the association of shift work and HDL cholesterol is significant: *p* = 0.009.

ANCOVA, analysis of covariance; BCOPS, Buffalo Cardio-metabolic Occupational Police Stress; CI, confidence interval; HDL, high-density lipoprotein; LDL, low-density lipoprotein; SE, standard error.

Table 4
Mean values of lipid biomarkers by levels of sleep quality, stratified by gender; BCOPS 2004–2009

	Sleep quality			<i>p</i>
	Good (≤ 5)	Intermediate (6–8)	Poor (≥ 9)	
Women	<i>n</i> = 43	<i>n</i> = 19	<i>n</i> = 37	
Triglycerides				
Model 1	57.7 (49.3–67.6)	68.4 (53.9–86.9)	76.6 (64.5–90.9)	0.004
Model 2	56.8 (48.5–66.4)	63.8 (49.7–81.9)	71.8 (59.7–86.4)	0.013
Total cholesterol				
Model 1	182.8 ± 5.3	201.5 ± 8.1	203.0 ± 5.8	0.013
Model 2	182.1 ± 5.4	198.3 ± 8.6	200.1 ± 6.3	0.030
HDL cholesterol				
Model 1	55.4 ± 2.3	66.4 ± 3.5	57.1 ± 2.5	0.560
Model 2	54.8 ± 2.2	63.8 ± 3.6	54.7 ± 2.6	0.967
LDL cholesterol				
Model 1	114.8 ± 4.7	118.6 ± 7.2	127.7 ± 5.1	0.127
Model 2	115.0 ± 4.8	119.3 ± 7.6	128.4 ± 5.6	0.125
Men	<i>n</i> = 119	<i>n</i> = 74	<i>n</i> = 68	
Triglycerides				
Model 1	116.7 (103.7–131.4)	126.9 (109.2–147.5)	135.6 (115.9–158.6)	0.051
Model 2	101.7 (89.2–116.0)	109.3 (93.2–128.2)	115.3 (97.8–136.0)	0.083
Total cholesterol				
Model 1	201.5 ± 3.5	207.0 ± 4.4	210.7 ± 4.6	0.154
Model 2	194.8 ± 3.9	198.9 ± 4.7	204.0 ± 4.9	0.185
HDL cholesterol				
Model 1	42.4 ± 1.1	40.9 ± 1.4	43.1 ± 1.4	0.904
Model 2	42.0 ± 1.3	40.7 ± 1.5	43.2 ± 1.6	0.696
LDL cholesterol				
Model 1	130.8 ± 3.1	136.1 ± 4.0	133.0 ± 4.2	0.919
Model 2	127.4 ± 3.6	131.5 ± 4.4	130.0 ± 4.5	0.935

The *p* values were obtained from linear regression.

Results for triglycerides are means (95% CI); all other results are means ± SE.

Model 1: adjusted for age.

Model 2: adjusted for age and race/ethnicity.

BCOPS, Buffalo Cardio-metabolic Occupational Police Stress; CI, confidence interval; HDL, high-density lipoprotein; LDL, low-density lipoprotein; SE, standard error.

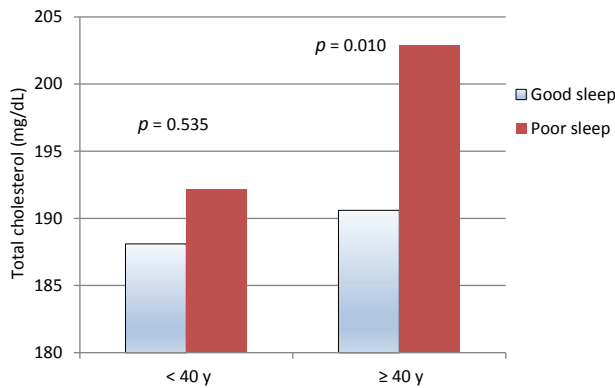


Fig. 1. Adjusted mean values of total cholesterol by levels of sleep quality, stratified by age; BCOPS 2004–2009. The models were adjusted for gender and race/ethnicity. Age significantly modified the association between sleep quality and total cholesterol ($p = 0.015$). BCOPS, Buffalo Cardio-metabolic Occupational Police Stress.

colleagues [30,31] reported that low HDL cholesterol concentrations were found in shift workers and persisted after adjustment for age and socioeconomic factors. In a study involving strictly rotating shift workers ($n = 98$; 3 8-hour shifts) and day-shift-only workers ($n = 100$), mean levels of HDL cholesterol were 8% lower in shift workers [14].

We identified one study that investigated the association between sleep quality and HDL cholesterol. In a cross-sectional study conducted in China, the association between HDL cholesterol and sleep quality was not statistically significant [33].

4.4. Shift work, sleep quality, and LDL cholesterol

Our results showed that neither shift work nor sleep quality was associated with the levels of LDL cholesterol. We identified very few studies that investigated the associations between shift work and

LDL cholesterol, and the results of these studies were not consistent with our findings. Van Amelsvoort et al [34] reported significant decreases in LDL cholesterol in shift workers, but compared with the 1-year change for daytime workers, this decrease was not significant. Among 424 Iranian rail road workers, elevated levels of LDL cholesterol were significantly more prevalent in shift workers, irrespective of age [35]. Shift work was defined as work at times other than normal daylight hours from approximately 7:00 AM to 6:00 PM or work during the weekends. Haseli-Mashhadi and colleagues [33] found significantly higher mean levels of LDL cholesterol among those who reported average or poor sleep quality compared with those with good sleep quality.

4.5. Reasons for inconsistent findings

It is possible that different definitions of shift work (i.e., rotating vs. fixed, 8 hours vs. 12 hours) may be partially responsible for the contradictory results. The number of years worked on a shift schedule may be another factor that plays a role in the discrepant findings. Suwazono and colleagues [36] conducted a prospective cohort study to determine the threshold number of years of work, alternating between three shifts, that was associated with a relative increase in serum TC levels. They found that a 5% increase in TC level was caused by ≥ 21 years of working three shifts (among the middle-aged workers). Other possible factors contributing to different results are the number of days off between shifts, our objective assessment of shift work versus self-report by other investigators, and different demographic characteristics of the study population.

4.6. Biological mechanisms

There are at least two possible mechanisms whereby shift work and poor sleep quality can be related to higher lipid levels. One of these mechanisms, and possibly the most important, is through the

Table 5
Adjusted mean values of all biomarkers by levels of shift work plus sleep quality, stratified by gender; BCOPS 2004–2009

	Day + good sleep	Day + poor sleep	A/N + good sleep	A/N + poor sleep	<i>p</i>
Women	<i>n</i> = 31	<i>n</i> = 37	<i>n</i> = 12	<i>n</i> = 19	
Triglycerides					
Model 1	56.7 (47.1–68.4)	70.3 (58.9–83.9)	60.9 (44.7–82.9)	80.4 (62.7–103.2)	0.116
Model 2	56.6 (47.0–68.1)	66.2 (54.7–80.0)	57.7 (42.2–78.9)	74.9 (57.7–97.3)	0.291
Total cholesterol					
Model 1	174.8 ± 6.1	203.1 ± 5.8	204.0 ± 10.2	200.9 ± 8.2	0.004
Model 2	174.7 ± 6.2	201.2 ± 6.3	202.3 ± 10.4	198.7 ± 8.7	0.014
HDL cholesterol					
Model 1	53.2 ± 2.7	59.6 ± 2.6	61.2 ± 4.5	61.6 ± 3.7	0.192
Model 2	53.1 ± 2.7	57.5 ± 2.8	59.3 ± 4.5	59.0 ± 3.8	0.513
LDL cholesterol					
Model 1	109.2 ± 5.5	125.6 ± 5.2	129.8 ± 9.1	122.5 ± 7.4	0.103
Model 2	109.3 ± 5.5	127.0 ± 5.7	131.0 ± 9.3	124.1 ± 7.8	0.089
Men	<i>n</i> = 45	<i>n</i> = 28	<i>n</i> = 74	<i>n</i> = 114	
Triglycerides					
Model 1	119.6 (98.4–145.5)	120.4 (93.1–155.8)	114.9 (98.8–133.6)	133.8 (118.3–151.4)	0.451
Model 2	111.4 (91.7–135.2)	106.8 (82.6–138.0)	95.4 (80.7–112.9)	112.6 (98.1–129.2)	0.359
Total cholesterol					
Model 1	200.6 ± 5.7	219.7 ± 7.5	202.0 ± 4.4	206.0 ± 3.6	0.168
Model 2	197.5 ± 5.7	212.4 ± 7.6	192.7 ± 5.0	198.0 ± 4.1	0.170
HDL cholesterol					
Model 1	43.0 ± 1.8	46.2 ± 2.4	42.1 ± 1.4	40.9 ± 1.1	0.244
Model 2	42.7 ± 1.9	46.4 ± 2.4	41.5 ± 1.6	40.6 ± 1.3	0.207
LDL cholesterol					
Model 1	127.8 ± 5.2	142.3 ± 6.8	132.7 ± 4.0	132.7 ± 3.3	0.389
Model 2	126.2 ± 5.3	137.4 ± 7.0	128.0 ± 4.6	129.1 ± 3.8	0.594

The *p* values were obtained from ANCOVA.

Results for triglycerides were first log-transformed then back-transformed for reporting. Results for triglycerides are means (95% CI); all other results are means ± SE. Model 1: adjusted for age.

Model 2: adjusted for age and race/ethnicity.

A/N, afternoon/night shift; ANCOVA, analysis of covariance; BCOPS, Buffalo Cardio-metabolic Occupational Police Stress; CI, confidence interval; HDL, high-density lipoprotein; LDL, low-density lipoprotein; SE, standard error.

disruption of circadian rhythms. An endogenous circadian pacemaker, located in the suprachiasmatic nuclei of the anterior hypothalamus, controls the daily 24-hour rhythms [37,38]. Plasma cholesterol and triglycerides show circadian variations [39]. Night shift work is associated with both sleep deprivation and disrupted melatonin production (Burch JB et al, 2005) [40] and melatonin plays a key role in the circadian rhythms [41]. Two proteins involved in circadian regulation, CLOCK (which stands for circadian locomotor output cycles kaput) and nocturnin, play an important role in the regulation of dietary lipid absorption [42]. CLOCK plays a role in turning off the genes involved in lipid absorption at the onset of the day, and CLOCK deficiency increases lipid absorption. CLOCK disruption triggers lipid accumulation in the liver [43]. Nocturnin deficiency decreases lipid absorption [42]. There is ample evidence in the literature of the effect of circadian disruption on the physiology of lipids and other substances [38,39,43].

Another mechanism whereby shift work may be related to adverse lipid levels is through diet. Research shows that night shift workers are more likely to eat foods that are less healthy, that is, high in simple carbohydrates and saturated fats [7,44]. One study showed that shift workers tended to decrease the intake of dietary fiber and increase the intake of saccharose, which might be responsible for changes in serum lipoproteins [7]. Another study reported that the total energy intake of workers on night shifts was higher than that of fixed day workers, but only among the older age groups (≥ 30 years) [45]. In a nationally representative sample of US workers, all shift workers, specifically rotating shift workers, tended to have more proinflammatory diets [46].

4.7. Limitations and strengths

There are a few limitations of this study that must be mentioned. Owing to the cross-sectional design of this study, causal inference cannot be made, nor can the chronological sequence of the main variables be determined. In our review of the literature, shift work was defined in various ways, making it challenging to directly compare the results of our study with those of others. Another limitation is that sleep quality was self-reported; however, this is likely to be a minor limitation since there has been good correlation between self-reported and objective measures of sleep quality [47]. The number of officers taking lipid-lowering medications was very small, making stratification by this variable challenging. In addition, the relatively small number of women may have contributed to the borderline associations observed, for example, in the association between shift work and HDL cholesterol. The results of our study should not be generalized to all workers. However, our results may be generalizable to police officers who are affiliated with departments of similar size and geographic locations.

One of the major strengths of this study is our use of objective measures of shift work. Unlike the studies that we reviewed, which often used self-reported assessment for shift work, our study was able to use objectively collected shift work information from the City of Buffalo daily payroll records. In addition, to the best of our knowledge, this was the first study to investigate the joint effect of shift work and sleep quality on lipid biomarkers among law enforcement officers.

In summary, shift work status was not significantly associated with any of the lipid measures. Sleep quality was significantly associated with triglycerides and TC among female officers only; mean levels of both lipid biomarkers gradually increased as sleep quality worsened. No significant associations were observed among male officers, and reasons for this are unclear. A combination of day shift work and good sleep quality was associated with lower mean levels of TC in female officers. Health programs for police officers

could include education and recommendations for good health practices that mitigate the effects of shift work and poor sleep habits on health. Future studies, employing larger sample sizes and longitudinal study designs, will be useful in determining whether night shift work and poor sleep quality are associated with any of the other lipid biomarkers and whether they predict subsequent adverse changes in lipid biomarkers. Studies are also needed to elucidate the reasons for significant associations between sleep quality and shift work/sleep quality only among women.

Conflicts of interest

All authors have no conflicts of interest to declare.

Disclaimer

The findings and conclusions of this report are those of the authors and do not necessarily represent the views of the National Institute for Occupational Safety and Health.

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