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Associations of Objectively Measured and Self-Reported Sleep Duration With Carotid Artery Intima Media Thickness Among Police Officers

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Abstract

Background—We aimed to examine the association of objectively measured and self-reported sleep duration with carotid artery intima media thickness (IMT) among 257 police officers, a group at high risk for cardiovascular disease (CVD).

Methods—Sleep duration was estimated using actigraphic data and through self-reports. The mean maximum IMT was the average of the largest 12 values scanned bilaterally from three angles of the near and far wall of the common carotid, bulb, and internal carotid artery. Linear and quadratic regression models were used to assess the association of sleep duration with IMT.

Results—Officers who had fewer than 5 or 8 hr or more of objectively measured sleep duration had significantly higher maximum IMT values, independent of age. Self-reported sleep duration was not associated with either IMT measure.

Conclusion—Attainment of sufficient sleep duration may be considered as a possible strategy for atherosclerosis prevention among police officers.

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Keywords

carotid artery intima media thickness; occupational epidemiology; sleep duration; actigraphy

INTRODUCTION

Accumulating evidence has shown that both short and long duration of sleep are associated with increased cardiovascular mortality [Gallicchio and Kalesan, 2009], incidence of cardiovascular disease (CVD) [Cappuccio et al., 2011], as well as CVD major risk factors such as high cholesterol [Gangwisch et al., 2010], incidence of Type 2 diabetes [Beihl et al., 2009; Cappuccio et al., 2010; Zizi et al., 2010], and prevalence of metabolic syndrome [Choi et al., 2008; Hall et al., 2008]. Measurement of carotid artery intima media thickness (IMT) has been used to study subclinical atherosclerosis, and is widely adopted as a surrogate marker for predicting CVD [Tewari et al., 2004; Ali et al., 2006; Polak, 2009; Verhamme et al., 2010].

Previous studies have reported inconsistent associations of self-reported and objectively measured sleep duration with IMT [Wolff et al., 2008; Abe et al., 2011; Nakazaki et al., 2012; Sands et al., 2012]. A U-shaped association between self-reported sleep duration and common carotid artery IMT found in one general population [Wolff et al., 2008] was not replicable in another general population [Abe et al., 2011]. Moreover, researchers have found an inverse linear association between objectively measured sleep duration and maximum IMT [Nakazaki et al., 2012; Sands et al., 2012].

Due to the nature of policing, police officers often experience unpredictable circumstances, and are exposed to several occupational stressors such as chemical hazards, traumatic events, shift work, long work hours, sleep deprivation, and other organizational stressors [Vila, 2006; Violanti et al., 2006; Zimmerman, 2012]. Larger carotid artery IMT values have been reported in police officers than in a general population sample, which were not fully explained by conventional CVD risk factors [Joseph et al., 2009]. Sleep disorders have been associated with an increased prevalence of self-reported comorbid physical and mental health conditions such as diabetes, CVD, and depression among North American police officers [Grandner and Pack, 2011; Rajaratnam et al., 2011]. Whether inadequate sleep duration or sleep deprivation contributes to higher IMT among police officers is unclear.

We aimed to investigate if objectively measured and self-reported sleep duration were associated with two IMT measurements: mean common carotid artery IMT and mean maximum IMT.

METHODS

Study Sample

Data collected from the Buffalo Cardio-Metabolic Occupational Police Stress study were utilized in the present analyses. The Buffalo Cardio-Metabolic Occupational Police Stress study aims to examine associations between physiological biomarkers of stress, subclinical metabolic and vascular disease markers, lifestyle, and psychosocial symptomatology among

police officers with a cross-sectional study design. All active duty police officers (N =710) in the Buffalo Police Department in New York were invited to participate in this study. Two officers who were pregnant at the time of examination were excluded. Four hundred sixty-four (65.4%) officers provided informed consent and were examined during the period of 2004–2009.

Among the 464 officers, three hundred fifty-four wore an Octagonal Motionlogger Sleep Watch (Cat. #26.100 Ambulatory Monitoring, Inc. Ardsley, NY). Of these 354, we excluded 88 participants: seven of them with insufficient actigraphic data (<3 days), 35 whose data were not compliant with study protocols, and 46 with corrupted data, leaving 266 officers with sufficient actigraphic sleep data. Of these, nine participants with either missing IMT values or self-reported sleep duration were excluded, yielding a sample of 257 participants for the present analyses. This study was approved by the Internal Review Board of the State University of New York at Buffalo, and the Human Subjects Review Board of the National Institute for Occupational Safety and Health.

Assessment of Sleep

Actigraphy—The methods for obtaining measured sleep duration from the actigraph were similar to that used in a previous study [Slaven et al., 2006]. Briefly, each participant was instructed to wear the actigraph throughout a 15-day work cycle that included 4 days of work, 4 days off work, 4 days back at work, and 3 days off. Since the device was not waterproof, participants were allowed to remove it while bathing or swimming. The actigraph measures movements using a piezoelectric bimorph-ceramic cantilevered beam, which generates a voltage each time the actigraph is moved. These voltages are gathered continuously and stored in 1-min epochs. Data were collected in four modes of zero crossings, proportional integration mode, time above threshold, and life channel. The proportional integration mode has yielded the highest correlation with polysomnography measured sleep time compared with other modes [Girardin et al., 2001], therefore data collected in this mode were used in the present study. The life channel is extremely sensitive to micro-vibrations such as pulse and respiration, and was used to distinguish if the actigraph was worn during the study period.

An Octagonal Motionlogger Computer Interface with ACT #25.111PS and the first version of analysis software Action4 (cat.# 21.123, Ambulatory Monitoring, Inc.) were employed to generate sleep parameters. Specifically, after the records were downloaded into Action4, a statistician scored the sleep records collected in the proportional integration mode. The University of California San Diego algorithm was used to determine sleep/wake status, and no hand scoring was employed to supplement the automated scoring. These results were entered into an Excel file. All data files were examined for data quality. Records with long periods of no data collection, or areas with truncated data, or those of fewer than 3 consecutive days of good quality data were deleted. A statistical test using a K-statistic based on the life channel records as described in a previous study [Slaven et al., 2006] was used as a secondary means of screening for data quality control, in addition to examining each record by hand.

The K-statistic helped researchers detect actigraphic data with poor quality caused by file corruption or participant noncompliance. It was calculated using the Euclidean Distance equation $K = [x^2 + y^2]^{1/2}$, in which x and y represent the average amplitude of consecutive time points and the average of distance between consecutive time points. By graphing data points of x and y, data points with poor quality could be visually distinguished from those with good quality. A cut-off value K_c was calculated by taking the mean of the largest value in the poor quality data cluster and the smallest value in the good quality data cluster. The K-statistic of each data point was compared with K_c to determine the data quality. If $K > K_c$, data quality was good. If $K < K_c$ data quality was poor.

Self-report—Each participant completed the Pittsburgh Sleep Quality Index questionnaire, designed to measure sleep quality over a 30-day interval. This questionnaire included 19 self-rated questions assessing sleep quality related factors that were grouped into seven components—self-reported sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleep medications, and daytime dysfunction. Each component was scored by summing the individual scores for each item. Each item was weighted equally on a 0–3 scale. A global sleep quality score was derived by summing the seven component scores with a possible range of 0–21. The lower the score, the better the sleep quality [Buysse et al., 1989].

Assessment of IMT

Details of the methods used for IMT measurement in the Buffalo Cardio-Metabolic Occupational Police Stress study have been described previously [Joseph et al., 2009; Hartley et al., 2011b]. Briefly, a standardized B-mode ultrasound protocol was used. This protocol was adopted from the Center for Medical Ultrasound at Wake Forest University, NC, where sonographers and readers received training and certification. B-mode ultrasound (Biosound Esaote, Indianapolis, IN) examinations were performed with a nominal center transducer frequency of 7.5–10 MHz. Both right and left sides of the extra-cranial carotid artery were scanned at three angles bilaterally. IMT was defined as the combined thickness of the intima and media layers. It was measured in 10 mm segments [near and far walls] of the distal common carotid, bifurcation, and proximal internal carotid artery. Mean common carotid IMT was derived as the average of the common carotid IMT measured at 12 sites in the right and left common carotid artery. Mean maximum IMT was the average of the maximum IMT measured at 12 sites on both the right and left sides of the neck and in the far and near walls of the common carotid, bifurcation, and internal carotid artery. Super VHS video cassettes were used to record images, and later digitized for reading on-site using Image Pro Plus software (Media Cybernetics, Inc. Silver Spring, MD). Calibration of the B-mode ultrasound device was performed every 2 weeks using a tissue equivalent phantom scan. Sixty-four scans were double read for quality assurance. Pearson correlation coefficients from replicate studies were 0.90 for common carotid IMT, and 0.96 for mean maximum IMT.

Assessment of Covariates

Anthropometric and biological measurements were performed by trained staff. Abdominal height (anteroposterior diameter) was derived from an average of three measurements that

were within 0.5 cm of each other [Charles et al., 2008]. Systolic blood pressure was taken after the participants had been resting at least 5 min. Three readings were taken. The average of the second and third readings was used in analysis. Blood samples were drawn from participants after a 12-hr fast. Assessments of chemistry and lipid profiles including glucose, low-density lipoprotein (LDL) cholesterol, and high-density lipoprotein (HDL) cholesterol were made using the Beckman Coulter LX20 clinical chemistry analyzer [Mikolaenko et al., 2000].

Demographic, medical history, psychological, and lifestyle variables were obtained from self-reported and interviewer-administered questionnaires. Information on lipid lowering medications was obtained from self-reported medical history. Perceived stress was obtained through the Perceived Stress Scale questionnaire with 14 items assessing stressful situations on a 5-point scale. The 5-point scale represents how often each perceived stressful situation occurred during the past month as follows: 0 (never), 1 (almost never), 2 (sometimes), 3 (fairly often), and 4 (very often). A perceived stress score was calculated by reverse coding ($0\rightarrow4$, $1\rightarrow3$, $2\rightarrow2$, $3\rightarrow1$, $4\rightarrow0$) the seven positive items (4, 5, 6, 7, 9, 10, and 13) and then summing the resulting scores for the 14 items to obtain an overall score [Cohen et al., 1983]. Depressive symptoms were assessed using the Center for Epidemiological Studies Depression questionnaire, a 20-item instrument with a 4-point scale and responses ranging from "rarely" to "most of the time" (< 1 day, 1–2 days, 3–4 days, 5–7 days during the past week) [Radloff, 1977]. A depressive symptom score was obtained by summing each score of 20 items (reverse coding the positive items 4, 8, 12, and 16). Physical activity information for the previous 7 days was collected using the 7-Day Recall questionnaire [Sallis et al., 1985]. A total physical activity index (score) was computed by summing the products of intensity and duration [Ma et al., 2011]. Alcohol intake per week was derived from a diet history. One drink was defined as a 12-ounce can or bottle of beer, one medium glass of wine, or one shot of liquor. Smoking status was defined as current, former, or never. Shift work was derived from payroll records that were available on a daily basis from 1994 to the date of examination. As described previously [Charles et al., 2007], dominant shift categorized as day, afternoon, or midnight was defined as the shift in which the participant spent most of his/ her work time during the study period.

Statistical Analyses

Both measured and self-reported sleep duration were categorized into five groups: <5.0, 5.0–5.9, 6.0–6.9, 7.0–7.9, and 8.0 hr/day. A weighted kappa statistic (κ_w) was calculated to test the agreement between the two sleep metrics. A value of 1.0 represents perfect agreement, while a value of 0.0 represents no agreement. Negative values indicate observed agreement is less than chance. A cut-point of 0.4 was used for poor agreement [Fleiss et al., 2003]. The frequency of agreement between self-reported and measured sleep within each sleep category was calculated. Due to the small proportion of Hispanic participants, race/ethnicity was collapsed into two groups: African American versus White/ Hispanic. To remove the inherent association between sleep duration and the Pittsburgh Sleep Quality Index global score, component 3 (sleep duration) was subtracted from the global score when adjustment for sleep quality as a potential confounder was performed. A variable that was either associated with both sleep and IMT in the present analyses or has been recognized as a

confounder in previous studies [Wolff et al., 2008; Cappuccio et al., 2011; Sands et al., 2012] was considered as a confounder for adjustment. Potential confounders included age, gender, race/ethnicity, abdominal height, systolic blood pressure, anti-hypertensive medications, glucose, LDL, HDL, lipid lowering medications, physical activity, alcohol consumption, perceived stress, a depressive symptom score, sleep quality, smoking status, shift work, and working a second job. First order additive interaction involving measured sleep and these variables was tested, but none was statistically significant.

Descriptive statistics were used to characterize the study population. Age-adjusted Pearson correlation coefficients were used to examine the associations of continuous variables with both sleep and IMT. A simple linear regression model was used to examine the relationship of each covariate with over-estimation of sleep duration using self-reported minus objectively measured sleep hours. A general linear model was used to investigate the association of potential categorical confounders with sleep and IMT controlling for age. Linear trends in IMT were tested by fitting linear regression models, while quadratic trends were tested using two methods: (a) by fitting a regression model that included a quadratic term for sleep duration (in continuous form) and (b) by specifying orthogonal polynomial contrast coefficients for the five-level categorical sleep duration variable. In supplemental analyses, a four-level categorical sleep duration variable was derived by collapsing 7.0–7.9 and 8.0 hr as 7 hr. The aforementioned linear and quadratic trends were further examined for the four-level categorical sleep duration variable. *P*-values were set at 0.20 for interaction terms and at 0.05 for all other tests. All analyses were performed using SAS version 9.2 (SAS Institute, Cary, NC).

RESULTS

Although only 55.4% of the 464 participants who were enrolled in the Buffalo Cardio-Metabolic Occupational Police Stress study had sufficient objective sleep data, their characteristics were similar to those without objective sleep data except for fasting glucose which was slightly lower (92.1 vs. 95.4 mg/dl, respectively, *P* = 0.025, data not shown).

This study cohort was relatively young with a mean age of 42.2 years, and a range from 21 to 74 years (Table I). Measured sleep was slightly less than 6 hr on average. Self-reported sleep was 0.4 hr longer than measured sleep. Mean common carotid artery IMT was 0.619 mm and mean maximum IMT was 0.907 mm. A majority of the participants were white (82.7%), male (73.9%), and working on an irregular shift (59.8%). About one-third of participants had a second job.

In the present study population, the weighted kappa coefficient between self-reported and measured sleep duration was 0.039 (95% CI: –0.03–0.11; Table II). Among the 257 police officers, 22% of them had a concordance between self-reported and objectively measured sleep categories. A majority of officers over-reported their sleep duration (58%). Self-reported sleep duration showed evidence of systematic disagreement with objectively measured sleep. Participants with shorter objectively measured sleep were more likely to over-report their sleep hours, while those with longer measured sleep tended to under-estimate their sleep duration.

Several variables were associated with under- or overestimation of sleep hours (Table III). Positive coefficients indicated overestimation by self-report, while negative coefficients indicated underestimation. Abdominal height and using anti-hypertensive medications were associated with over-reporting of sleep duration. A higher score on sleep quality, depressive symptoms, perceived stress, and physical activity index were associated with under-reporting of sleep hours.

After adjustment for age, abdominal height was negatively correlated with measured sleep and positively correlated with common carotid IMT (Table IV). Male officers and those taking anti-hypertensive medications had significantly fewer hours of measured sleep and larger values of both IMT metrics. Participants working a second job exhibited a significantly greater mean value of maximum IMT, compared with those who did not have a second job (0.937 mm vs. 0.883 mm, $P = 0.016$).

A U-shaped association was evident between measured sleep and mean maximum IMT ($P = 0.029$ for the age-adjusted quadratic trend) (Table V). Participants with (a) fewer than 5 hr or (b) 8 hr or more of measured sleep had higher values of mean maximum IMT. Lower maximum IMT values were observed among the three middle sleep categories (5.0–8.0 hr). Unadjusted and multivariable adjusted quadratic regression models exhibited borderline significant associations of measured sleep with mean maximum IMT (P values for quadratic trend were 0.079 and 0.051, respectively). Self-reported sleep was not associated with either common carotid IMT or mean maximum IMT in this sample (Table VI). In a supplemental analysis, we collapsed the two sleep categories of 7.0–7.9 and 8.0–10.7 into one (7.0 hr). The U-shaped association was no longer evident (data not shown).

DISCUSSION

The present study aimed to investigate the association of objectively measured and self-reported sleep duration with mean common carotid artery IMT and mean maximum IMT among police officers. A U-shaped association was observed between objectively measured sleep and mean maximum IMT, but self-reported sleep duration was not associated with either common carotid IMT or mean maximum IMT.

Studies investigating the associations of sleep duration with carotid artery IMT are sparse. To our knowledge, only four studies have reported findings on these associations. Two of them used objectively measured sleep duration and both found an inverse linear association between sleep duration and IMT [Nakazaki et al., 2012; Sands et al., 2012]. The linear trend in these two studies might be due to sleep categorization. More than 8 hr of sleep has been associated with an increased CVD risk in previous longitudinal studies [Ferrie et al., 2007; Amagai et al., 2010; Chien et al., 2010; Knutson, 2010; Nagai et al., 2010; Sabanayagam and Shankar, 2010]. Due to the small sample size, 7–8 and >8 hr of sleep were collapsed into single 7 hr category in the previous two studies [Nakazaki et al., 2012; Sands et al., 2012]. This approach might mask a U-shaped association between sleep and IMT when it existed. In our supplemental analyses, the U-shaped association was no longer evident when we collapsed the upper two sleep categories. Our findings suggest that combining sleep

categories in studies investigating sleep duration and health outcomes may obscure underlying U-shaped associations.

In the present study, objectively measured sleep duration was not associated with common carotid IMT. This inconsistent association of objectively measured sleep duration with the two IMT metrics was also observed in a previous study [Sands et al., 2012]. Early atherosclerotic lesions at different segments have been found to be closely associated with each other through sharing some common traditional CVD risk factors [Solberg and Eggen, 1971; Howard et al., 1994]. On the other hand, CVD risk factors for IMT progression may also vary by segment [Howard et al., 1994; Schott et al., 2004; Weber, 2009; Polak et al., 2010]. Due to the systemic and focal developmental nature of atherosclerosis within the carotid bed [Howard et al., 1994], some investigators [Espeland et al., 1999; Riley, 2002] have suggested that using a composite IMT score across segments might provide measures that were less sensitive to measurement errors and a more statistically powerful assessment of atherosclerosis and IMT progression. However, IMT measurements assessed in the internal carotid artery and bifurcation were more likely to include plaques if they were present [Zureik et al., 2000]. Therefore, whether the internal carotid and bifurcation IMT were more sensitive locations than common carotid artery IMT in detecting associations with sleep duration needs to be confirmed using IMT free of plaques.

In contrast to results obtained with the objectively measured sleep duration, self-reported sleep duration was not associated with common carotid and mean maximum IMT. Our results are inconsistent with those of two previous studies. One found a U-shaped association between self-reported sleep and IMT [Wolff et al., 2008], and the other reported that only long sleep duration (7 hr) was associated with higher IMT compared with 6 hr of sleep [Abe et al., 2011].

There might be several explanations for our non-significant associations. First, based on a commonly used criterion [Fleiss et al., 2003], there was not a good agreement between self-reported and objectively measured sleep duration. The disagreement seemed to be systematic in that shorter sleepers generally tended to over-report their sleep duration while longer sleepers tended to under-report it. On the other hand, the level of agreement was lower than that in other populations [Lauderdale et al., 2008; Van Den Berg et al., 2008]. This systematic disagreement might further mask the U-shaped association illustrated by the objectively measured sleep duration.

Certain participant characteristics were associated with over- or under-estimation of sleep duration in this particular sample. For example, participants with greater abdominal height or those taking anti-hypertensive medications tended to overestimate their sleep duration, whereas those with worse sleep quality, higher stress, higher depressive symptom scores, and higher physical activity index scores were more likely to underestimate sleep duration. For sleep promotion in CVD prevention in the law enforcement workforce, participants with higher values of these characteristics may need objective sleep screening.

Second, the positive relationship between sleep quality and IMT might weaken the association between self-reported sleep duration and IMT. Poor sleep quality has been

hypothesized as one of the possible underlying mechanisms between long sleep duration and CVD [Grandner and Drummond, 2007; Stamatakis and Punjabi, 2007]. Therefore, participants who reported longer sleep duration were expected to have a higher sleep quality score (i.e., poorer sleep). However, in the present study, longer sleep duration was accompanied by a lower sleep quality score. To investigate this finding further, we examined the results by removing the sleep quality variable from the models. The pattern of the associations between self-reported sleep and IMT remained similar. Our findings suggested that the disagreement between self-reported and objectively measured sleep duration was the major factor contributing to the nonsignificant association between self-reported sleep duration and IMT. Also, the Pittsburgh Sleep Quality Index may need to be validated in the law enforcement population.

Gender differences in the associations of sleep duration with IMT have been reported in a study that included 58% women [Sands et al., 2012]. However, we did not observe any statistically significant gender differences. The relatively small number of females may have reduced the likelihood of detecting effect modification if it were present. Another possible reason may be that the gender disparities in physical and psychological factors related to CVD among this unusual cohort are smaller than that among the general population [Fry and Greenfeld, 1980]. Further epidemiological studies need to be conducted in a larger police cohort with similar male and female proportions to confirm these results or investigate these associations separately by gender when sample sizes are adequate. An incidental finding in the present study was that officers working a second job had fewer hours of objectively measured sleep hours and higher mean maximum IMT than those not working a second job. It may be worthwhile to investigate the pathways that might account for the association between second job and IMT.

Several potential underlying mechanisms for increased IMT among participants with short sleep duration have been proposed previously. Faraut et al. [2011] reviewed well-controlled laboratory studies to identify immune and inflammatory related biological changes leading to atherosclerosis development after short sleep restriction: (1) sleep restriction activates non-specific immune parameters (i.e., certain leukocyte populations); (2) sleep restriction induces an increase in the plasma protein expression of myeloperoxidase and myeloperoxidase-oxidized LDL levels; (3) restricted sleep increases the levels of cardiovascular risk markers, such as C-reactive protein or pro-inflammatory cytokines; and (4) the levels of neutrophils and interleukin-6 in blood are increased when sleep is restricted.

However, the biological mechanisms accounting for larger IMT values among participants with extended sleep hours (i.e., 8 hr) remain unclear. Longitudinal studies have suggested that long sleep duration increases the CVD risk [Cappuccio et al., 2011]. More investigations are needed to explore the potential mechanisms linking long objectively measured sleep hours and IMT.

A plausible explanation for the association of longer sleep duration with larger maximum IMT value in the present study may be obstructive sleep disorder, which is common in North American police officers [Rajaratnam et al., 2011]. Sleep apnea has been found to be associated with IMT [Ciccone et al., 2012]. However, Wattanakit et al. [2008] suggested

that the positive association between apnea and atherosclerosis can be attributed to CVD risk factors. Lack of clinical assessment of sleep apnea in the present study precluded our further exploration of the role that apnea might play in the association of sleep with IMT. Future studies are warranted to explore whether the association of sleep duration with IMT is modified or confounded by apnea.

This study has a few potential limitations. First, due to the cross-sectional study design, we were not able to determine whether a causal relationship exists between sleep duration and IMT. In addition, selection bias might have been introduced if those who chose to participate differed from the target population of all police officers in the department. However, the similarity in frequency distributions of age and sex between the Buffalo Cardio-Metabolic Occupational Police Stress study population and the Buffalo Police Department currently working population suggests that selection bias, if present, is likely to be minimal.

Second, the healthy worker effect may limit the generalizability of these findings to a general population or to other working groups. Due to the unique occupational nature of law enforcement (e.g., exposure to strenuous physical activity, violent events, shift work, and long working hours), being mentally and physically healthy is the fundamental criterion for applicants to enter this workforce. This healthy worker effect may be greater in recently hired officers, but less evident with increasing years of service as a police officer, a pattern indicated by a study reporting the health disparities between police officers and a general working population [Hartley et al., 2011a]. Third, the relatively young age in this cohort may limit the generalization of our findings to an older population, since the relationship of sleep duration with CVD has been shown to vary significantly by age [Fang et al., 2012; Magee et al., 2012].

Despite the above limitations, the present study also has major strengths. Although sleep duration determined by actigraphy is not identical to that determined by polysomnography, these two measures have been reported to be highly correlated in normal sleepers with a correlation coefficient of 0.9 and above [Sadeh et al., 1995]. To our knowledge, this was the first study to use both objectively measured and self-reported sleep duration to investigate the association of these two sleep metrics with IMT which made it possible to compare the consistency of results as suggested by previous investigators [Van Den Berg et al., 2008]. In addition, sleep hours may vary between days at work and days off. Police officers were therefore instructed to wear the actigraph for a whole shift cycle (15 days of combined onduty and offduty) which may reduce sleep measurement variability and increase precision, thus enhancing the potential for detection of the association between objective sleep and IMT.

In conclusion, police officers who had (a) fewer than 5 hr or (b) 8 hr or more of objectively measured sleep had significantly greater mean maximum IMT than those who slept 5.0–7.9 hr after adjusting for age. This association was attenuated slightly after adjustment for the other factors. A similar pattern was not observed between self-reported sleep and either IMT measurement. These results suggest that future studies are warranted to investigate whether maximum IMT is a superior surrogate marker of atherosclerosis compared to the mean

common carotid artery IMT. Self-reported sleep duration did not agree well with objectively measured sleep duration in this study population. Therefore, it may be advantageous to use multiple sleep metrics when the association of sleep duration with health outcomes is investigated. Due to the modifiable nature of sleep duration and the high prevalence of sleep deprivation in law enforcement and other first responders, benefits of atherosclerosis prevention through modifying sleep behavior may have a great public health impact should a causal relationship between sleep duration and IMT progression be established.

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TABLE I

Characteristics of Participants, Buffalo Cardio-Metabolic Occupational Police Stress Study, 2004–2009 (N = 257)

Variable	n	Mean (SD)
Self-reported sleep (hr)	257	6.1 (1.2)
Measured sleep (hr)	257	5.7 (1.3)
Common carotid artery IMT (mm)	257	0.619 (0.107)
Mean maximum IMT (mm)	257	0.907 (0.209)
Age (years)	257	42.2 (8.6)
Abdominal height (cm)	257	20.8 (3.2)
Glucose (mg/dl)	256	92.3 (10.9)
High-density lipoprotein (mg/dl)	256	46.6 (14.4)
Low-density lipoprotein (mg/dl)	254	125.4 (32.8)
Systolic bloodpressure (mm Hg)	257	121.1 (11.9)
Depressive symptoms	256	7.8 (7.0)
Perceived stress score	250	19.7 (7.9)
Alcohol intake (drinks/week)	255	5.0 (7.6)
Physical activity index	254	20.7 (17.8)
Sleep quality score[a]	246	5.2 (2.8)

Variable	n	%
Gender		
Male	190	73.9
Female	67	26.1
Race/ethnicity		
White	210	82.7
American	42	16.5
Hispanic	2	0.8
Anti-hypertensive medications		
Yes	34	13.2
No	223	86.8
Lipid lowering medication		
Yes	35	13.6
No	222	86.4
Smoking status		
Current	41	16.0
Former	76	29.7
Never	139	54.3
Shift work		
Day	97	40.3
Afternoon	84	34.9
Midnight	60	24.9

Variable	n	Mean (SD)
Second job		
Yes	90	35.9
No	161	64.1

[a]Calculated from the Pittsburgh Sleep Quality Index global score after removing the sleep duration component.

TABLE II

Frequency Distribution of Agreement Between Self-Reported and Objectively Measured Sleep Duration Within Each Sleep Category, Buffalo Cardio-Metabolic Occupational Police Stress Study, 2004–2009

Self-reported sleep duration (hr)	Objectively measured sleep duration (hr) (N = 257)				
(N = 257)	1.7–4.9 (n = 71)	5.0–5.9 (n = 83)	6.0–6.9 (n = 67)	7.0–7.9 (n = 26)	8.0–10.7 (n = 10)
3.0–4.9 (n = 21)	4	10	4	2	1
5.0–5.9 (n = 61)	16	21	17	6	1
6.0–6.9 (n = 81)	29	25	20	4	3
7.0–7.9 (n = 69)	15	24	17	10	3
8.0–10.0 (n = 25)	7	3	9	4	2

A weighted Kappa coefficient (κ_W) = 0.039 (95%CI: −0.03 to 0.11) [Fleiss et al., 2003] between the two sleep metrics.

Note: κ_W 0.4 represents poor agreement [Fleiss et al., 2003] between the two sleep metrics.

TABLE III

Simple Linear Association of Each Covariate With the Difference[*] Between Self-Reported and Objectively Measured Sleep Duration, Buffalo Cardio-Metabolic Occupational Police Stress Study, 2004–2009(N = 257)

Variable	β[a]	Standard error	P
Age (1 year)	−0.006	0.012	0.642
Abdominal height (1 cm)	0.098	0.032	0.003
Glucose (1 mg/dl)	0.001	0.010	0.884
Systolic blood pressure (1 mm Hg)	−0.009	0.009	0.334
Low-density lipoprotein (1 mg/dl)	−0.003	0.003	0.327
High-density lipoprotein (1 mg/dl)	−0.009	0.007	0.241
Sleep quality score[b] (1 U)	−0.194	0.035	<0.001
Perceived stress score (1 U)	−0.036	0.013	0.006
Depressive symptoms score (1 U)	−0.046	0.015	0.002
Physical activity index (1 U)	−0.017	0.006	0.004
Alcohol intake (1 drink)	0.004	0.014	0.767
Gender (female = 1, male = 2)	0.329	0.237	0.167
Race/ethnicity (black = 0, white/Hispanic =1)	−0.730	0.279	0.124
Anti-hypertensive medications (yes)	0.804	0.304	0.009
Lipid lowering medication (yes)	0.037	0.305	0.903
Smoking status (reference: never smoking)			
Current	−0.327	0.297	0.272
Former	−0.057	0.238	0.810
Second job (yes)	0.072	0.220	0.744d
Shift work (reference: day shift)			
Afternoon	0.013	0.253	0.959
Midnight	−0.026	0.279	0.925

[*] Self-reported sleep duration minus objectively measured sleep duration.

[a] Positive coefficients indicated overestimation by self-report, while negative coefficients indicated underestimation.

[b] Calculated from Pittsburgh Sleep Quality Index global score after removing the sleep duration component.

TABLE IV

Age-adjusted Associations of Selected Covariates With Sleep Duration and Intima Media Thickness (IMT), Buffalo Cardio-Metabolic Occupational Police Stress Study, 2004–2009 (N = 257)

Variable	Measured sleep (hr) R	P	Self-reported sleep (hr) R	P	Common carotid IMT (mm) r	P	Mean maximum IMT (mm) r	P
Abdominal height (cm)	−0.2503	<0.001	−0.0041	0.948	0.1613	0.010	0.0900	0.152
Glucose (mg /dl)	−0.1371	0.029	−0.1262	0.044	0.0463	0.462	0.0380	0.545
Low-density lipoprotein (mg/dl)	0.0489	0.439	−0.0327	0.604	0.1209	0.055	0.2064	0.001
High-density lipoprotein (mg/dl)	0.0927	0.140	−0.0016	0.980	−0.0824	0.190	−0.0778	0.216
Systolic blood pressure (mm Hg)	−0.0670	0.285	−0.1549	0.013	0.1708	0.006	0.0874	0.163
Depressive symptoms score	0.0918	0.144	−0.1661	0.008	0.0458	0.467	−0.0261	0.678
Perceived stress score	0.1086	0.087	−0.1261	0.047	−0.0654	0.303	−0.0349	0.583
Alcohol intake (drinks/per week)	−0.0686	0.276	−0.0500	0.432	0.0079	0.901	−0.0110	0.861
Physical activity index	0.0795	0.208	−0.1637	0.009	0.0138	0.827	0.0686	0.277
Sleep quality score[a]	0.0421	0.512	−0.4155	<0.001	−0.0762	0.235	−0.1444	0.024

Variable	Measured sleep (hr) Mean (SD)	P	Self-reported sleep (hr) Mean (SD)	P	Common carotid IMT (mm) Mean (SD)	P	Mean maximum IMT (mm) Mean (SD)	P
Gender								
Male	5.6 (0.1)	0.018	6.1 (0.1)	0.521	0.627 (0.006)	0.012	0.930 (0.012)	<0.001
Female	6.0 (0.2)		6.0 (0.2)		0.595 (0.011)		0.840 (0.021)	
Race/ethnicity								
African American	5.1 (0.2)	0.001	5.9 (0.2)	0.171	0.627 (0.014)	0.531	0.884 (0.027)	0.349
White/Hispanic	5.8 (0.1)		6.2 (0.1)		0.618 (0.006)		0.911 (0.012)	
Anti-hypertensive medications								
Yes	5.1 (0.2)	0.004	6.3 (0.2)	0.349	0.659 (0.016)	0.007	0.972 (0.031)	0.025
No	5.8 (0.1)		6.1 (0.1)		0.613 (0.006)		0.897 (0.012)	
Lipid lowering medication								
Yes	5.7 (0.2)	0.867	6.3 (0.2)	0.495	0.626 (0.016)	0.664	0.929 (0.032)	0.465
No	5.7 (0.1)		6.1 (0.1)		0.618 (0.006)		0.903 (0.012)	
Smoking status								

Variable	Measured sleep (hr)		Self-reported sleep (hr)		Common carotid IMT (mm)		Mean maximum IMT (mm)	
	R	P	R	P	r	P	r	P
Current	5.8 (0.2)	0.520	5.9 (0.2)	0.318	0.636 (0.014)	0.229	0.933 (0.027)	0.499
Former	5.8 (0.2)		6.3 (0.1)		0.623 (0.011)		0.891 (0.021)	
Never	5.6 (0.1)		6.1 (0.1)		0.611 (0.008)		0.907 (0.015)	
Second job								
Yes	5.5 (0.1)	0.091	6.0 (0.1)	0.164	0.623 (0.009)	0.556	0.937 (0.018)	0.016
No	5.8 (0.1)		6.2 (0.1)		0.616 (0.007)		0.883 (0.013)	
Shift work								
Day	5.8 (0.1)	0.592	6.2 (0.1)	0.287	0.617 (0.009)	0.941	0.894 (0.018)	0.526
Afternoon	5.8 (0.1)		6.2 (0.1)		0.620 (0.010)		0.924 (0.019)	
Midnight	5.6 (0.2)		5.9 (0.2)		0.623 (0.012)		0.914 (0.022)	

P-values for differences between group means.

r, Pearson correlation coefficient.

[a] Calculated from Pittsburgh Sleep Quality Index global score after removing the sleep duration component.

TABLE V

Unadjusted and Adjusted Mean Intima Media Thickness (IMT) Values (Standard Errors) Across Categories of Objectively Measured Sleep Duration, Buffalo Cardio-Metabolic Occupational Police Stress Study, 2004–2009 (N = 257)

IMT(mm)	Measured sleep (hr)					p^a	p^b	p^c
	1.7–4.9 (n = 71)	5.0–5.9 (n = 83)	6.0–6.9 (n = 67)	7.0–7.9 (n = 26)	8.0–10.7 (n = 10)			
Common carotid artery								
Unadjusted	0.638 (0.113)	0.613 (0.115)	0.616 (0.105)	0.601 (0.082)	0.605 (0.053)	0.125	0.616	0.962
Age-adjusted	0.635 (0.010)	0.613 (0.010)	0.621 (0.010)	0.593 (0.017)	0.611 (0.028)	0.205	0.512	0.803
Age-gender-race adjusted	0.632 (0.011)	0.615 (0.010)	0.621 (0.011)	0.599 (0.018)	0.610 (0.028)	0.413	0.687	0.725
Multivariable adjusted	0.633 (0.012)	0.617 (0.010)	0.623 (0.012)	0.590 (0.019)	0.625 (0.027)	0.757	0.360	0.692
Mean maximum								
Unadjusted	0.963 (0.268)	0.882 (0.171)	0.878 (0.171)	0.893 (0.174)	0.939 (0.231)	0.099	0.079	0.265
Age-adjusted	0.958 (0.020)	0.883 (0.019)	0.887 (0.021)	0.876 (0.033)	0.950 (0.054)	0.159	0.029	0.298
Age-gender-race adjusted	0.953 (0.021)	0.887 (0.018)	0.888 (0.021)	0.886 (0.033)	0.944 (0.053)	0.312	0.056	0.342
Multivariable adjusted[d]	0.953 (0.023)	0.895 (0.019)	0.892 (0.022)	0.865 (0.037)	0.946 (0.052)	0.342	0.051	0.316

[a] From linear regression.

[b] Quadratic association from orthogonal polynomial contrasts coefficients.

[c] Quadratic trend from quadratic regression.

[d] Adjusted for age, gender, race/ethnicity, abdominal height, systolic blood pressure, anti-hypertensivemedications, glucose, low-densitylipoprotein, high-density lipoprotein, lipid lowering medications, sleep quality (Pittsburgh Sleep Quality Index global score after removing sleep duration component), perceived stress score, depressive symptoms score, physical activity index, smoking status, shift work, and having a second job.

TABLE VI

Unadjusted and Adjusted Mean Intima-Media Thickness (IMT) Values (Standard Errors) Across Categories of Self-Reported Sleep Duration, Buffalo Cardio-Metabolic Occupational Police Stress Study, 2004–2009 (N = 257)

IMT(mm)	Self-reported sleep (hr)					p^a	p^b	p^c
	3.0–4.9 (n = 21)	5.0–5.9 (n = 61)	6.0–6.9 (n = 81)	7.0–7.9 (n = 69)	8.0–10.0 (n = 25)			
Common carotid artery								
Unadjusted	0.659 (0.085)	0.612 (0.083)	0.623 (0.133)	0.619 (0.103)	0.588 (0.082)	0.311	0.813	0.473
Age-adjusted	0.643 (0.019)	0.609 (0.011)	0.622 (0.010)	0.624 (0.011)	0.601 (0.018)	0.904	0.841	0.419
Age-gender-race adjusted	0.644 (0.019)	0.608 (0.011)	0.619 (0.010)	0.627 (0.011)	0.607 (0.018)	0.882	0.623	0.303
Multivariable adjusted	0.657 (0.024)	0.615 (0.012)	0.624 (0.011)	0.617 (0.012)	0.607 (0.020)	0.645	0.463	0.830
Mean maximum								
Unadjusted	0.938 (0.134)	0.887 (0.188)	0.924 (0.250)	0.909 (0.191)	0.866 (0.217)	0.638	0.792	0.896
Age-adjusted	0.905 (0.038)	0.879 (0.022)	0.922 (0.019)	0.919 (0.021)	0.893 (0.035)	0.583	0.684	0.827
Age-gender-race adjusted	0.914 (0.037)	0.876 (0.022)	0.915 (0.019)	0.923 (0.021)	0.906 (0.035)	0.452	0.923	0.930
Multivariable adjusted[d]	0.939 (0.045)	0.891 (0.023)	0.921 (0.021)	0.913 (0.023)	0.876 (0.038)	0.738	0.898	0.833

[a] From linear regression.

[b] Quadratic association from orthogonal polynomial contrasts coefficients.

[c] Quadratic trend from quadratic regression.

[d] Adjusted for age, gender, race/ethnicity, abdominal height, systolic blood pressure, anti-hypertensive medications, glucose, low-density lipoprotein, high-density lipoprotein, lipid lowering medications, sleep quality (Pittsburgh Sleep Quality Index global score after removing sleep duration component), perceived stress score, depressive symptoms score, physical activity index, smoking status, shift work, and having a second job.