Author Manuscript

Author Manuscript

Author Manuscript

Author Manuscript

HHS Public Access

Author manuscript

J Occup Environ Med. Author manuscript; available in PMC 2015 October 08.

Published in final edited form as:

J Occup Environ Med. 2013 November ; 55(11): 1323–1328. doi:10.1097/JOM.0b013e3182a299c9.

Association Between Shiftwork and Glomerular Filtration Rate in Police Officers

Luenda E. Charles, PhD, MPH, **Ja K. Gu, MSPH**, **Desta Fekedulegn, PhD**, **Michael E. Andrew, PhD**, **John M. Violanti, PhD**, and **Cecil M. Burchfiel, PhD, MPH**

Biostatistics and Epidemiology Branch (Dr Charles, Ms Gu, Dr Fekedulegn, Dr Andrew, and Dr Burchfiel), Health Effects Laboratory Division, National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention, Morgantown, WVa; and Department of Social and Preventive Medicine (Dr Violanti), School of Public Health and Health Professions, State University of New York at Buffalo.

Abstract

Objective—To investigate associations between shiftwork and glomerular filtration rate among white/Hispanic (n = 273) and African American (n = 81) police officers.

Methods—Analysis of variance/analysis of variance was utilized to compare mean values of estimated glomerular filtration rate (eGFR) across shiftwork categories.

Results—Shiftwork was significantly associated with eGFR among white/Hispanic officers only: day (88.6 ± 2.8), afternoon (90.6 ± 2.9), and night shift (83.1 ± 3.1 mL/min/1.73 m^2); afternoon versus night, P = 0.007. Percentage of hours worked on the night shift was inversely associated with mean levels of eGFR, trend P = 0.001. Body mass index modified the association between shiftwork and eGFR (interaction P = 0.038). Among officers with body mass index 25 kg/m^2 or higher, those who worked the night shift had the lowest mean eGFR (afternoon vs night, P = 0.012; day vs night, P = 0.029).

Conclusions—Night-shift work was associated with decreased kidney function among white/Hispanic officers. Longitudinal studies are warranted among all races.

The prevalence of chronic kidney disease (ie, estimated glomerular filtration rate [eGFR] < 60 mL/min/1.73 m^2) has increased since 1988-1994 among men and women of all ethnic groups in the United States.[1,2] Among persons older than 65 years, there was a 5.9-fold increase in recognized chronic kidney disease between 1995 (1.5%) and 2010 (8.9%) among whites, and a 4.7-fold increase between 1995 (2.9%) and 2010 (13.7%) among African Americans.[1] Chronic kidney disease is responsible for a large burden of hospitalizations and deaths.[1,3,4] The economic burden of chronic kidney disease is also high. Reports show that in 2010, the medical costs for Medicare patients (aged ≥65 years) with chronic kidney disease were US $41 billion.[1]

Address correspondence to: Luenda E. Charles, PhD, MPH, National Institute for Occupational Safety and Health, HELD/BEB, MS L-4050, 1095 Willowdale Rd, Morgantown, WV 26505 (lcharles@cdc.gov)..

The authors declare no conflicts of interest.

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

Cardiovascular disease, which has been shown to be strongly associated with kidney disease,[3,4] is the number one cause of morbidity and mortality in the United States.[5] The prevalence of cardiovascular disease (CVD) is believed to be higher among law enforcement officers than among the general population.[6] CVD and several metabolic disorders are known to be increased among shiftworkers.[7-12] Shiftwork may also be associated with kidney function. In an experimental study conducted on hamsters, Martino and colleagues[13] showed that circadian disruption played a critical role in cardiac and renal disease. Among industrial workers at an organochlorine plant, shiftwork (rather than exposure to the nephrotoxic solvents) was demonstrated to cause albuminuria.[14] There is strong evidence that the kidney is one of many organs that possesses an intrinsic circadian clock.[15,16]

Shiftwork, regardless of how it is defined, is becoming increasingly prevalent in many occupations all over the world and is mandatory in several professions, one of which is law enforcement.[10] Because of the substantial public health burden and implications of exposure to both shiftwork and kidney disease, investigation of the relationship of both factors could be useful to occupational clinicians and investigators. To the best of our knowledge, there are no published studies that have investigated the association between shiftwork and biomarkers of kidney function in population-based studies. Furthermore, police officers are exposed to several occupational stressors,[17] are known to have a higher prevalence of cardiovascular-related illnesses than the general population,[6] and, in general, are an understudied occupational group. The objective of this study is to examine the cross-sectional association between shiftwork and eGFR, a commonly used measure of kidney function, among police officers. Another marker of kidney function, cystatin C, has been shown to be related to age, gender, and ethnicity.[18] Because of the known associations of kidney function with these variables, we will also assess effect modification by gender and body mass index (BMI).[18-20]

METHODS

Study Participants

The participants in this study were police officers employed at the Buffalo New York Police Department. From June 2004 through October 2009, 464 police officers (from an estimated 710 officers in 2004) agreed to participate and were examined in the Buffalo Cardiometabolic Occupational Police Stress study. Women officers who were pregnant at the time of examination were excluded. Prior to any clinic examinations, the officers reviewed and signed informed consent forms. The data were collected at the Center for Health Research, School of Public Health and Health Professions, University at Buffalo, and State University of New York.[21] 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, exclusions included retired officers (n = 30), and officers with missing information on shiftwork (n = 34) and GFR (n = 41). The sample size for this current study includes 354 officers—81 women and 273 men.

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

Assessment of Shiftwork Status

Electronic work history data from the City of Buffalo, New York, payroll records were available from 1994 to 2010 on a daily basis. The database contained information regarding the activities for each officer and included the start and end time of work, the type of activity (ie, regular work, overtime work, court appearances), the type of leave (ie, weekend, vacation, work-related injury, other types of sick leave), and the number of hours worked on each activity. Two shiftwork variables were developed from these data: (1) dominant shift (day, afternoon, night) and (2) percentage of time worked on the night shift. The time participants started their shift for the regular time work 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 AM and 11:59 AM; afternoon shift if the start time was between 12 PM and 7:59 PM; and night shift if the start time was between 8 PM and 3:59 AM.

The Buffalo, New York, police department instituted fixed or permanent shifts for their officers in 1994; however, officers occasionally worked other shifts such as in situations where they worked for another officer absent on some type of leave. The total number of hours worked by each officer was obtained by summing over all records from 1994 to the date of examination. Then, hours worked on the day, afternoon, and night shifts were calculated. An officer's dominant shift was defined as the shift on which he/she worked the largest number of hours. For example, the dominant shift for an officer who worked 10% on the day shift, 5% on the afternoon shift, and 85% on the night shift would be night shift.

Assessment of eGFR

Glomerular filtration rate is a method that is commonly used to measure kidney function.[22] All blood specimens were collected after the officers had fasted for a minimum of 12 hours. Creatinine was measured in serum using the Abbott Architect (Abbott Laboratories, Abbott park, IL). The eGFR was calculated using the abbreviated MDRD (Modification of Diet in Renal Disease) Study equation, which is based on serum creatinine values, age, gender, and race/ethnicity. Values of eGFR were calculated for both non-African Americans and African American ethnicities. The MDRD formula is as follows: eGFR (mL/min per 1.73 m^2; 1.21) = 186.3 × serum creatinine (exp[−1.154]) × Age (exp[−0.203]) × (0.742 if female) × (1.21 if African American). Values of eGFR of 60 to 90 mL/min/1.73 m^2 are considered normal. Levels of eGFR decrease naturally by 0.5 to 1.0 mL/min/1.73 m^2 per year of age as part of the normal aging process. Values of eGFR of less than 60 mL/min/1.73 m^2 is indicative of chronic kidney disease and less than 15 mL/min/1.73 m^2 of kidney failure.

Assessment of Covariates

Officers completed self- and interviewer-administered questionnaires, providing information on demographic characteristics, lifestyle behaviors, and medical history. Officers reported their smoking status as current, former, or never. Body mass index was calculated as weight (in kilograms) divided by height (in meters squared). Physical activity during the previous 7 days was obtained with the Seven-Day Physical Activity Recall questionnaire used in the Stanford Five-City Project.[23] Sleep duration and quality were assessed using the Pittsburgh Sleep Quality Index questionnaire.[24]

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

Statistical Analysis

Simple descriptive measures were calculated for all variables. Associations of all covariates with the exposures (dominant shift and percentage of hours worked on the night shift) and the outcome (eGFR) were examined using the Pearson correlation coefficient, chi-square test of independence, and analysis of variance. All analyses pertaining to eGFR were performed separately for whites/Hispanics and African Americans. Analysis of variance and analysis of co-variance were utilized to compare the mean values of eGFR across shiftwork status and to examine the trends of eGFR across tertiles of percentage of hours worked on the night shift. Percentage of hours worked was originally a continuous variable that was categorized into tertiles to present mean values of eGFR, which facilitate interpretation of the results. In all analyses investigating the association between the percentage of hours worked on the night shift and eGFR, the *P* values for linear trends were obtained from linear regression models utilizing the continuous forms of both dependent and independent variables. Effect modification was assessed for gender, physical activity, sleep duration, and sleep quality. Confounders were selected on the basis of their significant associations with both the independent and dependent variables and/or if these variables were shown to be confounders in previous studies. Age and gender were first adjusted for in the multivariate models. Then, several CVD-related factors that are known to be associated with kidney function[25-27] were added to the models and they included systolic blood pressure, diastolic blood pressure, use of antihypertensive medications, total cholesterol, low-density lipoprotein cholesterol, glucose, BMI, and smoking status. All analyses were conducted in SAS version 9.2 (SAS Institute Inc, Cary, NC).[28]

RESULTS

Descriptive statistics of all variables are presented separately for white/Hispanic and African American officers to correspond with the subsequent analyses (Table 1). The majority of officers were white/Hispanic (77.1%). The mean (± SD) ages of white/Hispanic and African American officers were 40.8 ± 6.7 and 41.5 ± 5.4 years, respectively. Women comprised approximately one quarter of the white/Hispanic officers and one third of the African American officers. The prevalence of chronic kidney disease (eGFR < 60 mL/min/1.73 m^2) was very low, 1.8% among white/Hispanic officers and 2.5% among African American officers.

The age-adjusted associations between selected characteristics and eGFR are shown separately for white/Hispanic and African American officers in Table 2. Mean levels of eGFR were not significantly different between women and men among white/Hispanic or among African American officers. Duration of police service was significantly and positively correlated with eGFR among white/Hispanic ($r = 0.173$; $P = 0.004$) but not among African American officers ($r = 0.120$; $P = 0.289$). Total cholesterol was significantly and positively correlated among African American officers ($r = 0.290$; $P = 0.009$) but not among white/Hispanic officers ($r = -0.065$; $P = 0.288$). Triglycerides were significantly associated with eGFR among African American ($r = 0.312$, $P = 0.004$) but not among white/Hispanic officers ($r = 0.048$, $P = 0.430$).

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

Several demographic and lifestyle characteristics were found to be significantly associated with shiftwork status after age adjustment (data not shown). They include years of service (fewer mean years for night shift officers compared with officers on the other shifts), and BMI and abdominal height (higher mean values for afternoon and night shift officers compared with officers who worked the day shift). Officers on day shift had significantly lower mean levels of glucose, systolic blood pressure, and diastolic blood pressure, and higher mean levels of high-density lipoprotein cholesterol and sleep duration than officers who worked the night and afternoon shift.

Mean values of eGFR are presented across shiftwork separately for white/Hispanic and African American officers in Table 3. Shiftwork was significantly associated with kidney function among white/Hispanic but not among African American officers. In the unadjusted model, white/Hispanic officers who worked on the afternoon shift had the highest mean level of eGFR (94.0 ± 22.3 mL/min/1.73 m^2) and officers who worked the night shift had the lowest mean level (87.0 ± 16.7 mL/min/1.73 m^2); $P = 0.015$. After adjustment for age and gender, the association was attenuated but the pattern remained. Further adjustment for several CVD-related risk factors resulted in further attenuation but the association remained statistically significant: day (88.6 ± 2.7 mL/min/1.73 m^2), afternoon (90.6 ± 2.9 mL/min/1.73 m^2), and night shift (83.1 ± 3.1 mL/min/1.73 m^2); $P = 0.026$. Post hoc comparisons revealed that the shifts responsible for this significant association with eGFR was afternoon versus night; $P = 0.007$.

Table 4 shows mean levels of eGFR presented across race-specific tertiles of the percentage of hours worked on the night shift. As in Table 3, the association between the percentage of hours worked on the night shift and eGFR was only statistically significant among white/Hispanic officers. Because the percentage of hours worked on the night shift increased, mean levels of eGFR significantly decreased among whites/Hispanic officers. Compared to the unadjusted model, the fully adjusted model showed a stronger monotonic inverse trend between the percentage of hours worked on the night shift and eGFR: first tertile (91.6 ± 2.8 mL/min/1.73 m^2), second tertile (88.5 ± 2.8 mL/min/1.73 m^2), and third tertile (82.2 ± 2.9 mL/min/1.73 m^2); $P = 0.001$.

Body mass index significantly modified the association between shiftwork status (but not the percentage of hours worked on the night shift) and eGFR but only among white/Hispanic officers (interaction $P = 0.038$). Models of the association between shiftwork and eGFR among white/Hispanic officers, stratified by BMI, are shown in Table 5. Among officers with BMI 25 kg/m^2 or higher, shiftwork was significantly associated with eGFR after adjustment for age and gender; $P = 0.015$. After further adjustment for CVD-related risk factors, the association between shiftwork and eGFR was slightly attenuated ($P = 0.023$). In this final model, the mean values of eGFR for the officers with BMI 25 kg/m^2 or higher were as follows: day shift (91.0 ± 3.2 mL/min/1.73 m^2), afternoon shift (89.2 ± 3.6 mL/min/1.73 m^2), and night shift (81.4 ± 3.8 mL/min/1.73 m^2); day versus night, $P = 0.029$ and afternoon versus night, $P = 0.012$. The association between shiftwork and eGFR was not statistically significant among white/Hispanic officers with BMI lower than 25 kg/m^2. Gender, sleep duration, sleep quality, and physical activity were not shown to be statistically

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

significant effect modifiers in any of the associations with eGFR among white/Hispanic or among African American officers.

DISCUSSION

In this cohort of police officers, shiftwork was significantly associated with kidney function as estimated by GFR, but only among the white/Hispanic police officers. White/Hispanic officers who worked the night shift had the lowest mean eGFR levels and those who worked the afternoon shift had the highest mean eGFR levels. Body mass index significantly modified the association between shiftwork and eGFR among white/Hispanic officers. Stratification by BMI showed that the association between shiftwork and eGFR was significant only among the white/Hispanic officers who had a BMI 25 kg/m^2 or higher and these results were similar to that observed in the unstratified models. Higher percentages of hours worked on the night shift were associated with lower mean levels of eGFR among white/Hispanic officers.

Factors that may play a role in the association between shiftwork and renal function include circadian disruption, poor sleep quality, and/or decreased sleep duration. We were unable to find studies that investigated the association between shiftwork and biomarkers of kidney function; however, reports of the association between circadian rhythms and the kidney has been known since the 19th century when physician Edward Smith, one of the pioneers of circadian physiology, published the first documented evidence of the circadian role in renal function.[15,16,29] Since then, several studies have confirmed and expanded on the role of circadian rhythms in the kidney. Laboratory experiments conducted on hamsters showed that circadian disruption played a critical role in cardiac and renal disease.[13] Boogaard and Caubo[14] conducted experiments on industrial workers to determine whether increased levels of urinary albumin were the result of exposure to organochlorines or shiftwork. Participants included (1) workers who were exposed to organochlorines and who were shiftworkers, (2) control group 1 (men who were shiftworkers), and (3) control group 2 (men who worked only during the daytime). Both control groups had no exposure to halogenated hydrocarbons. Their results showed that the day-shift workers had lower levels of urinary albumin whereas the exposed and first control group had similar and slightly higher urinary albumin levels suggesting that the increased albumin was only due to alterations in circadian rhythms.

It is well known that night-shift workers, in general, get inadequate sleep and have poor sleep quality.[30,31] Poor sleep quality is associated with blunting of the nocturnal dip (reduction) in blood pressure in participants with normal kidney function.[16,19] The diurnal profile of systolic and diastolic blood pressure in healthy persons demonstrates an increase in the early morning, a plateau during the day, and then a reduction during sleep.[16,19] Persons who do not exhibit a 10% to 20% decrease in blood pressure at night (compared to day) are classified as “nondippersò nondipping is associated with an increased risk of chronic kidney disease.[16,32] Nikolaeva and colleagues[33] found that the circadian timing system controls the daily rhythms of sodium and potassium excretion by the kidney, which suggests that dysfunction of these rhythms may have a significant influence on blood pressure. A longitudinal study showed that creatinine clearance declines more rapidly in

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

nondippers than in dippers, and urinary protein excretion is greater in the nondippers than in the dippers.[34] Short sleep duration, especially 5 or fewer hours, is known to lead to increased hypertension and increased proteinuria.[20,35] Data from National Health and Nutrition Examination Survey 1999-2006 show that chronic kidney disease was most prevalent among those with diagnosed hypertension, but persons with either undiagnosed or prehypertension accounted for more than one third of all cases of chronic kidney disease, representing an estimated 8 million US adults.[36] Prevalence of chronic kidney disease was found to be increased across the spectrum of blood pressure, with those with normal blood pressure having the lowest prevalence of chronic kidney disease and those with diagnosed hypertension having the greatest prevalence.[36]

Poor sleep quantity and quality are associated with increased levels of inflammation and oxidative stress[37,38] and are significant risk factors for type 2 diabetes,[39,40] suggesting major implications for chronic kidney disease due to the strong relationship between diabetes and chronic kidney disease.[41,42] In addition to the association between sleep and diabetes, studies also show a positive association between inadequate sleep duration and obesity.[43,44] There is substantial evidence that obesity may be an independent risk factor for chronic kidney disease.[19] Obesity is associated with oxidative stress,[45] and inflammation and oxidative stress adversely affect kidney function.[46,47]

We found significant associations between shiftwork and eGFR among white/Hispanic but not among African American officers. Reasons for these different findings between the racial/ethnic groups are unclear. Studies have shown that African Americans have a higher prevalence of kidney disease than white Americans.[1] It is possible that although other factors (eg, diabetes, hypertension, obesity) may be associated with kidney function in African Americans, shiftwork schedule may not be one of them. In the current study, African American officers who worked the night shift had the highest mean level of eGFR, which was just the opposite of the findings among the white/Hispanic officers. The MDRD formula used to calculate eGFR was designed to account for the greater than average muscle mass in African Americans compared to whites and it is possible for over- or underestimation of eGFR to occur within this group. Use of cystatin C (which does not need to take muscle mass into consideration)[48] to assess kidney function in a future study may confirm or disprove our findings among African Americans.

LIMITATIONS AND STRENGTHS

There are a few limitations that must be mentioned. Because of the cross-sectional design of this study, causal inference cannot be made nor can the chronological sequence of the main variables be determined. If officers who were initially scheduled on night or afternoon shift become ill and, as a result, are transferred to the day shift or resign, this may result in a bias which could dilute any association that may have been present. Another limitation is based on the fact that kidney problems are more likely to be observed among the elderly and our sample is that of a relatively young cohort. We were unable to compare these results of kidney function with measures of cystatin C because this variable is not currently available. The results of this study may only be generalizable to police officers who are affiliated with departments of similar size and geographic location.

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

This study also has several strengths. To our knowledge, this is the first study to investigate the association between shiftwork and kidney function among police officers or in any occupational group. Among highly stressed workers such as police officers, it is worthwhile to investigate whether CVD risk factors are associated with exposures that are related to the workplace. Availability of daily payroll records enabled us to obtain objective information on shiftwork and to create new variables. There was standardized and objective assessment of kidney function using the MDRD (modification of diet in renal disease) Study equation. Despite its flaws, the MDRD Study equation is useful for estimating eGFR in research and clinical practice because of its relative ease of calculation based on serum creatinine level, age, sex, and race.[22,49] It is clinically useful as a measure of eGFR up to 60 mL/min/1.73 m^2 because it was developed in a population with known chronic kidney disease.[22] In addition, the equation was updated in 2007 for use with serum creatinine measurements standardized to an assay traceable to isotope dilution mass spectroscopy.[50] There was specific assessment of eGFR by racial/ethnic groups, non-African Americans, and African Americans. The sample size was adequate for each racial/ethnic group, and we were able to adjust for confounders and assess for effect modification. The results of this study may be generalizable to officers in other police departments having similar size and other characteristics to the Buffalo Police Department.

CONCLUSIONS

In summary, white/Hispanic officers who worked the night shift had the lowest mean eGFR levels, and those who worked the afternoon shift had the highest mean eGFR levels. After stratification by BMI, the association was only significant among those officers with a BMI 25 kg/m^2 or higher. Additional analyses are warranted to determine why no significant associations were observed among African American officers. Future studies, employing larger sample sizes and other measures of kidney function that do not need to account for muscle mass (eg, cystatin C), should be employed to investigate whether shiftwork is associated with or is a risk factor for impairment of kidney function among African Americans.

Acknowledgments

Supported by the National Institute for Occupational Safety and Health, contract no. 200-2003-01580.

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

REFERENCES

1. National Institutes of Health. US Renal Data System 2012 Annual Data Report: Atlas of Chronic Kidney Disease and End-Stage Renal Disease in the United States. National Institutes of Health; Bethesda, MD: 2012.
2. Coresh J, Selvin E, Stevens LA, et al. Prevalence of chronic kidney disease in the United States. JAMA. 2007; 298:2038–2047. [PubMed: 17986697]
3. Keith DS, Nichols GA, Gullion CM, Brown JB, Smith DH. Longitudinal follow-up and outcomes among a population with chronic kidney disease in a large managed care organization. Arch Intern Med. 2004; 164:659–663. [PubMed: 15037495]

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

4. Sarnak MJ, Levey AS, Schoolwerth AC, et al. Kidney disease as a risk factor for development of cardiovascular disease: a statement from the American Heart Association Councils on Kidney in Cardiovascular Disease, High Blood Pressure Research, Clinical Cardiology, and Epidemiology and Prevention. Hypertension. 2003; 42:1050–1065. [PubMed: 14604997]
5. Kung HC, Hoyert DL, Xu J, Murphy SL. Deaths: final data for 2005. Natl Vital Stat Rep. 2008; 56:1–120. [PubMed: 18512336]
6. Zimmerman FH. Cardiovascular disease and risk factors in law enforcement personnel: a comprehensive review. Cardiol Rev. 2012; 20:159–166. [PubMed: 22314143]
7. De Bacquer D, Van Risseghem M, Clays E, Kittel F, De Backer G, Braeckman L. Rotating shift work and the metabolic syndrome: a prospective study. Int J Epidemiol. 2009; 38:848–854. [PubMed: 19129266]
8. Mohebbi I, Shateri K, Seyedmohammadzad M. The relationship between working schedule patterns and the markers of the metabolic syndrome: comparison of shift workers with day workers. Int J Occup Med Environ Health. 2012; 25:383–391. [PubMed: 23055229]
9. Shields M. Shift work and health. Health Rep. 2002; 13:11–33. [PubMed: 15069802]
10. Szosland D. Shift work and metabolic syndrome, diabetes mellitus and ischaemic heart disease. Int J Occup Med Environ Health. 2010; 23:287–291. [PubMed: 20934953]
11. Vyas MV, Garg AX, Iansavichus AV, et al. Shift work and vascular events: systematic review and meta-analysis. BMJ. 2012; 345:e4800. [PubMed: 22835925]
12. Wang XS, Armstrong ME, Cairns BJ, Key TJ, Travis RC. Shift work and chronic disease: the epidemiological evidence. Occup Med. 2011; 61:78–89.
13. Martino TA, Oudit GY, Herzenberg AM, et al. Circadian rhythm disorganization produces profound cardiovascular and renal disease in hamsters. Am J Physiol Regul Integr Comp Physiol. 2008; 294:R1675–R1683. [PubMed: 18272659]
14. Boogaard PJ, Caubo ME. Increased albumin excretion in industrial workers due to shift work rather than to prolonged exposure to low concentrations of chlorinated hydrocarbons. Occup Environ Med. 1994; 51:638–641. [PubMed: 7951797]
15. Firsov D, Bonny O. Circadian regulation of renal function. Kidney Int. 2010; 78:640–645. [PubMed: 20664559]
16. Stow LR, Gumz ML. The circadian clock in the kidney. J Am Soc Nephrol. 2011; 22:598–604. [PubMed: 21436284]
17. Fekedulegn D, Burchfiel CM, Violanti JM, et al. Associations of long-term shift work with waking salivary cortisol concentration and patterns among police officers. Ind Health. 2012; 50:476–86. [PubMed: 23047078]
18. Kottgen A, Selvin E, Stevens LA, Levey AS, Van Lente F, Coresh J. Serum cystatin C in the United States: the Third National Health and Nutrition Examination Survey (NHANES III). Am J Kidney Dis. 2008; 51:385–394. [PubMed: 18295054]
19. Turek NF, Ricardo AC, Lash JP. Sleep disturbances as nontraditional risk factors for development and progression of CKD: review of the evidence. Am J Kidney Dis. 2012; 60:823–833. [PubMed: 22727724]
20. Yamamoto R, Nagasawa Y, Iwatani H, et al. Self-reported sleep duration and prediction of proteinuria: a retrospective cohort study. Am J Kidney Dis. 2012; 59:343–355. [PubMed: 22019276]
21. Violanti JM, Burchfiel CM, Miller DB, et al. The Buffalo Cardio-Metabolic Occupational Police Stress (BCOPS) pilot study: methods and participant characteristics. Ann Epidemiol. 2006; 16:148–156. [PubMed: 16165369]
22. K/DOQI clinical practice guidelines for chronic kidney disease: evaluation, classification, and stratification. Am J Kidney Dis. 2002; 39:S1–S266. [PubMed: 11904577]
23. Sallis JF, Haskell WL, Wood PD, et al. Physical activity assessment methodology in the Five-City Project. Am J Epidemiol. 1985; 121:91–106. [PubMed: 3964995]
24. Buysse DJ, Reynolds CF III, Monk TH, Berman SR, Kupfer DJ. The Pittsburgh Sleep Quality Index: a new instrument for psychiatric practice and research. Psychiatry Res. 1989; 28:193–213. [PubMed: 2748771]

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

25. Kawamoto R, Kohara K, Tabara Y, Miki T. An association between metabolic syndrome and the estimated glomerular filtration rate. Intern Med (Tokyo, Japan). 2008; 47:1399–1406.
26. Ohno Y, Ishimura E, Naganuma T, et al. Prevalence of and factors associated with chronic kidney disease (CKD) in Japanese subjects without notable chronic diseases, undergoing an annual health checkup. Kidney Blood Press Res. 2012; 36:139–148. [PubMed: 23095841]
27. Thomas G, Sehgal AR, Kashyap SR, Srinivas TR, Kirwan JP, Navaneethan SD. Metabolic syndrome and kidney disease: a systematic review and meta-analysis. Clin J Am Soc Nephrol. 2011; 6:2364–2373. [PubMed: 21852664]
28. SAS. Inc.. SI. SAS/STAT 9.2 User's Guide. SAS Institute Inc.; Cary, NC: 2008.
29. Lavie P. Two 19th-century chronobiologists: Thomas Laycock and Edward Smith. Chronobiol Int. 1992; 9:83–96. discussion 97-101. [PubMed: 1568266]
30. Charles LE, Burchfiel CM, Fekedulegn D, et al. Shift work and sleep: the Buffalo Police Health Study. Policing: Int J Police Strateg Manage. 2007; 30:215–227.
31. Wang XS, Travis RC, Reeves G, et al. Characteristics of the Million Women Study participants who have and have not worked at night. Scand J Work Environ Health. 2012; 38:590–599. [PubMed: 22772745]
32. Drawz PE, Rosenthal N, Babineau DC, Rahman M. Nighttime hospital blood pressure—a predictor of death, ESRD, and decline in GFR. Renal Fail. 2010; 32:1036–1043.
33. Nikolaeva S, Pradervand S, Centeno G, et al. The circadian clock modulates renal sodium handling. J Am Soc Nephrol. 2012; 23:1019–1026. [PubMed: 22440902]
34. Timio M, Venanzi S, Lolli S, et al. "Non-dipper" hypertensive patients and progressive renal insufficiency: a 3-year longitudinal study. Clin Nephrol. 1995; 43:382–387. [PubMed: 7554522]
35. Puttonen S, Harma M, Hublin C. Shift work and cardiovascular disease: pathways from circadian stress to morbidity. Scand J Work Environ Health. 2010; 36:96–108. [PubMed: 20087536]
36. Crews DC, Plantinga LC, Miller ER III, et al. Prevalence of chronic kidney disease in persons with undiagnosed or prehypertension in the United States. Hypertension. 2010; 55:1102–1109. [PubMed: 20308607]
37. Hale L, Parente V, Dowd JB, et al. Fibrinogen may mediate the association between long sleep duration and coronary heart disease. J Sleep Res. 2013; 22:305–314. [PubMed: 23217092]
38. Hayes AL, Xu F, Babineau D, Patel SR. Sleep duration and circulating adipokine levels. Sleep. 2011; 34:147–152. [PubMed: 21286230]
39. Lou P, Chen P, Zhang L, et al. Relation of sleep quality and sleep duration to type 2 diabetes: a population-based cross-sectional survey. BMJ Open. 2012; 2:e000956.
40. Matthews KA, Dahl RE, Owens JF, Lee L, Hall M. Sleep duration and insulin resistance in healthy black and white adolescents. Sleep. 2012; 35:1353–1358. [PubMed: 23024433]
41. Liao MT, Sung CC, Hung KC, Wu CC, Lo L, Lu KC. Insulin resistance in patients with chronic kidney disease. J Biomed Biotechnol. 2012; 2012:691369. [PubMed: 22919275]
42. Plantinga LC, Crews DC, Coresh J, et al. Prevalence of chronic kidney disease in US adults with undiagnosed diabetes or prediabetes. Clin J Am Soc Nephrol. 2010; 5:673–682. [PubMed: 20338960]
43. Patel SR. Reduced sleep as an obesity risk factor. Obes Rev. 2009; 10(suppl 2):61–68. [PubMed: 19849803]
44. Zimberg IZ, Damaso A, Del Re M, et al. Short sleep duration and obesity: mechanisms and future perspectives. Cell Biochem Funct. 2012; 30:524–529. [PubMed: 22473743]
45. Charles LE, Burchfiel CM, Violanti JM, et al. Adiposity measures and oxidative stress among police officers. Obesity (Silver Spring, Md). 2008; 16:2489–2497.
46. Hiramoto JS, Katz R, Peralta CA, et al. Inflammation and coagulation markers and kidney function decline: the Multi-Ethnic Study of Atherosclerosis (MESA). Am J Kidney Dis. 2012; 60:225–232. [PubMed: 22560844]
47. Rebholz CM, Wu T, Hamm LL, et al. The association of plasma fluorescent oxidation products and chronic kidney disease: a case-control study. Am J Nephrol. 2012; 36:297–304. [PubMed: 22986784]

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

48. Seronie-Vivien S, Delanaye P, Pieroni L, et al. cystatin C: current position and future prospects. Clin Chem Lab Med. 2008; 46:1664–1686. [PubMed: 18973461]

49. Kramer H, Palmas W, Kestenbaum B, et al. Chronic kidney disease prevalence estimates among racial/ethnic groups: the Multi-Ethnic Study of Atherosclerosis. Clin J Am Soc Nephrol. 2008; 3:1391–1397. [PubMed: 18550650]

50. Levey AS, Coresh J, Greene T, et al. Expressing the Modification of Diet in Renal Disease Study equation for estimating glomerular filtration rate with standardized serum creatinine values. Clin Chem. 2007; 53:766–772. [PubMed: 17332152]

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

TABLE 1

Descriptive Statistics of Demographic and Other Characteristics by Racial/Ethnic Groups, BCOPS 2004-2009*

Characteristics	Whites/ Hispanics (*n* = 273), Mean ± SD/*N* (%)	African Americans (*n* = 81), Mean ± SD/*N* (%)	*P*
Age, yrs	40.8 ± 6.7	41.5 ± 5.4	0.293
BMI, Kg/m^2	29.0 ± 4.8	29.8 ± 4.7	0.194
Alcohol (drinks/wk)	5.3 ± 7.0	2.1 ± 5.0	<0.0001
Glucose (fasting), mg/dL	91.9 ± 10.7	92.3 ± 10.8	0.784
Total cholesterol, mg/dL	205.0 ± 38.0	187.9 ± 33.6	<0.001
LDL cholesterol, mg/dL	130.4 ± 33.8	121.3 ± 32.0	0.033
HDL cholesterol, mg/dL	46.9 ± 14.9	45.3 ± 14.0	0.390
Systolic blood pressure, mm Hg	120.2 ± 12.1	123.0 ± 12.0	0.062
Diastolic blood pressure, mm Hg	77.4 ± 9.8	79.0 ± 11.0	0.211
Night shift, % hrs	29.3 ± 32.7	19.6 ± 28.0	0.016
GFR, mL/min/1.73 m^2	89.9 ± 19.1	94.1 ± 20.9	NA†
Gender			0.115
Women	70 (25.6)	28 (34.6)	
Men	203 (74.4)	53 (65.4)	
Education			0.132
≤ HS/GED	26 (9.6)	12 (14.8)	
<4 yrs college	150 (55.2)	49 (60.5)	
≥4 yrs college	96 (35.3)	20 (24.7)	
Smoking status			0.001
Current	58 (21.3)	4 (5.1)	
Former	62 (22.7)	14 (18.0)	
Never	153 (56.0)	60 (76.9)	
BMI, Kg/m^2			0.568
Normal < 25.0	55 (20.2)	14 (17.3)	
Overweight ≥ 25	218 (79.9)	67 (82.7)	
Sleep quality			0.404
Good	115 (43.9)	37 (49.3)	
Poor	147 (56.1)	38 (50.7)	
Shiftwork			<0.0001
Day	85 (31.1)	48 (59.3)	
Afternoon	108 (39.6)	19 (23.5)	
Night	80 (29.3)	14 (17.3)	
Night shift, % hrs			0.026
First tertile	85 (31.1)	33 (40.7)	

Author Manuscript

Author Manuscript

Author Manuscript

Author Manuscript

Characteristics	Whites/ Hispanics (*n* = 273), Mean ± SD/*N* (%)	African Americans (*n* = 81), Mean ± SD/*N* (%)	*P*
Second tertile	87 (31.9)	31 (38.3)	
Third tertile	101 (37.0)	17 (21.0)	
Antihypertensive medications			<0.0001
No	251 (91.9)	60 (74.1)	
Yes	22 (8.1)	21 (25.9)	
GFR			NA[†]
<60 mL/min/1.73 m^2	5 (1.8)	2 (2.5)	
≥60 mL/min/1.73 m^2	268 (98.2)	79 (97.5)	

BCOPS indicates Buffalo Cardio-metabolic Occupational Police Stress; BMI, body mass index; GFR, glomerular filtration rate; GED, general education development; HS, high school.

[*] *P* values are for differences between women and men. For continuous variables, the *P* values were obtained from *t* tests. For categorical variables, the *P* values were obtained from chi-square or Fisher exact tests; Chronic kidney disease defined as GFR < 60 mL/min/1.73 m^2.

[†] *P* value is not applicable for GFR because different formulas were used for whites/Hispanic and African American officers.

Author Manuscript

Author Manuscript

Author Manuscript

Author Manuscript

TABLE 2

Age-Adjusted Associations Between Selected Characteristics and Estimated Glomerular Filtration Rate (eGFR), BCOPS 2004-2009*

	eGFR (mL/min/1.73 m^2)	
	Whites/Hispanics (*n* = 273)	**African Americans (*n* = 81)**
BMI, Kg/m^2	0.089, 0.145	0.007, 0.949
Glucose (fasting), mg/dL	−0.079, 0.195	−0.048, 0.671
Total cholesterol, mg/dL	−0.065, 0.288	0.290, 0.009
LDL cholesterol, mg/dL	−0.086, 0.159	0.233, 0.039
HDL cholesterol, mg/dL	−0.045, 0.458	−0.150, 0.183
Systolic blood pressure, mm Hg	0.002, 0.975	−0.036, 0.754
Diastolic blood pressure, mm Hg	0.001, 0.997	−0.056, 0.623
Gender		
Women	87.4 ± 2.2	93.7 ± 4.0
Men	90.7 ± 1.3	94.2 ± 2.9
P †	0.208	0.919
Smoking status		
Current	88.1 ± 2.5	92.7 ± 11.0
Former	93.8 ± 2.4	97.7 ± 6.1
Never	89.0 ± 1.5	93.6 ± 2.8
P †	0.186	0.819
Antihypertensive medications		
Yes	89.9 ± 1.2	96.0 ± 2.8
No	89.5 ± 4.1	88.5 ± 4.9
P †	0.927	0.206

* For continuous variables, Pearson correlation coefficient and *P* values.

† *P* values are for any difference between the means, obtained from ANOVA. ANOVA indicates analysis of variance; BMI, body mass index; eGFR, ; LDL, low-density lipoprotein; HDL, high-density lipoprotein.

Author Manuscript

Author Manuscript

Author Manuscript

Author Manuscript

TABLE 3

Mean Values of eGFR (mL/min/1.73 m^2) by Shiftwork Status, Stratified by Race/Ethnicity; BCOPS 2004-2009*

	Shiftwork Status			
	Day	**Afternoon**	**Night**	***P***
Whites/Hispanics	*n* = 85	*n* = 108	*n* = 80	
Model 1	87.3 ± 15.9	94.0 ± 22.3	87.0 ± 16.7	0.015
Model 2	89.7 ± 2.1	92.1 ± 2.1	84.1 ± 2.4	0.015
Model 3†	88.6 ± 2.8	90.6 ± 2.9	83.1 ± 3.1	0.026
African Americans	*n* = 48	*n* = 19	*n* = 14	
Model 1	96.2 ± 19.8	86.6 ± 27.0	96.9 ± 12.4	0.204
Model 2	96.6 ± 3.0	84.2 ± 5.3	95.7 ± 5.8	0.123
Model 3	96.9 ± 3.6	86.6 ± 5.8	99.7 ± 6.3	0.156

ANOVA indicates analysis of variance; ANCOVA, analysis of covariance; LDL, low-density lipoprotein.

*Model 1: Unadjusted; Model 2: Adjusted for age and gender; Model 3: Adjusted for age, gender, systolic blood pressure, diastolic blood pressure, use of antihypertensive medications, total cholesterol, LDL cholesterol, glucose, and smoking status. *P* values are for differences between the means and were obtained from ANOVA/ANCOVA.

†Whites/Hispanics: Afternoon vs day: $P = 0.537$; Afternoon vs night: $P = 0.007$; Day vs night: $P = 0.101$.

Author Manuscript

Author Manuscript

Author Manuscript

Author Manuscript

TABLE 4

Mean Values of eGFR (mL/min/1.73 m^2) by Race-Specific Tertiles of the Percentage of Midnight Hours Worked, Stratified by Race/Ethnicity; BCOPS 2004-2009*

	Midnight Hours Worked, %			
	First tertile	**Second tertile**	**Third tertile**	***P***
Whites/Hispanics	*n* = 91, Range (0–3.37)	*n* = 91, Range (3.45–35.31)	*n* = 91, Range (37.18–100)	
Model 1	91.8 ± 23.3	91.2 ± 15.8	86.6 ± 17.2	0.036
Model 2	93.1 ± 2.1	89.9 ± 2.0	83.4 ± 2.2	<0.001
Model 3	91.6 ± 2.8	88.5 ± 2.8	82.2 ± 2.9	0.001
African Americans	*n* = 27, Range (0–0.465)	*n* = 27, Range (0.467–15.99)	*n* = 27, Range (17.25–94.13)	
Model 1	94.1 ± 22.0	93.7 ± 17.3	94.4 ± 23.6	0.615
Model 2	94.8 ± 4.4	93.0 ± 4.4	94.0 ± 4.4	0.790
Model 3	92.7 ± 5.0	97.2 ± 5.4	97.4 ± 5.1	0.245

LDL indicates low-density lipoprotein.

*Model 1: Unadjusted; Model 2: Adjusted for age and gender; Model 3: Adjusted for age, gender, systolic blood pressure, diastolic blood pressure, use of antihypertensive medications, total cholesterol, LDL cholesterol, glucose, and smoking status. *P* values are for linear trend and were obtained from linear regression models.

Author Manuscript

Author Manuscript

Author Manuscript

Author Manuscript

TABLE 5

Mean Values of eGFR (mL/min/1.73 m^2) by Shiftwork Status, Stratified by BMI, Among White/Hispanic Officers; BCOPS 2004-2009*

	Shiftwork Status							
	BMI < 25 kg/m^2				BMI ≥ 25 kg/m^2			
	Day (*n* = 25)	Afternoon (*n* = 16)	Night (*n* = 14)	*P*	Day (*n* = 60)	Afternoon (*n* = 92)	Night (*n* = 66)	*P*
Model 1	83.0 ± 13.4	97.2 ± 22.8	90.9 ± 16.9	0.044	89.1 ± 16.6	93.5 ± 22.3	86.2 ± 16.7	0.061
Model 2	85.2 ± 4.6	96.6 ± 4.7	90.0 ± 5.0	0.223	91.0 ± 2.6	90.8 ± 2.7	82.4 ± 3.0	0.015
Model 3†	86.1 ± 9.7	96.4 ± 8.2	89.9 ± 9.1	0.343	91.0 ± 3.2	89.2 ± 3.6	81.4 ± 3.8	0.023

ANOVA indicates analysis of variance; eGFR, estimated glomerular filtration rate.

*Model 1: Unadjusted; Model 2: Adjusted for age and gender; Model 3: Adjusted for age, gender, systolic blood pressure, diastolic blood pressure, use of antihypertensive medications, total cholesterol, LDL cholesterol, glucose, and smoking status. *P* values are for any difference between the means, obtained from ANOVA.

†Interaction by BMI: $P = 0.038$. BMI ≥25 kg/m^2 only: Afternoon vs day: $P = 0.839$; Afternoon vs night: $P = 0.012$; Day vs night: $P = 0.029$.