HHS Public Access

Author manuscript

Am J Hum Biol. Author manuscript; available in PMC 2019 January 02.

Published in final edited form as:

Am J Hum Biol. 2017 September 10; 29(5): . doi:10.1002/ajhb.22996.

Police work stressors and cardiac vagal control

Michael E. Andrew[1], **John M. Violanti**[2], **Ja K. Gu**[1], **Desta Fekedulegn**[1], **Shengqiao Li**[3], **Tara A. Hartley**[1], **Luenda E. Charles**[1], **Anna Mnatsakanova**[1], **Diane B. Miller**[4], and **Cecil M. Burchfiel**[1]

[1]Biostatistics and Epidemiology Branch, Health Effects Laboratory Division, National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention, Morgantown, West Virginia

[2]Department of Epidemiology and Environmental Health, School of Public Health and Health Professions, State University of New York at Buffalo, New York

[3]Anthem Inc., Department of Provider Analytics, Indianapolis, Indiana

[4]Toxicology and Molecular Biology Branch, Health Effects Laboratory Division, National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention, Morgantown, West Virginia

Abstract

Objectives: This study examines relationships between the frequency and intensity of police work stressors and cardiac vagal control, estimated using the high frequency component of heart rate variability (HRV).

Methods: This is a cross-sectional study of 360 officers from the Buffalo New York Police Department. Police stress was measured using the Spielberger police stress survey, which includes exposure indices created as the product of the self-evaluation of how stressful certain events were and the self-reported frequency with which they occurred. Vagal control was estimated using the high frequency component of resting HRV calculated in units of milliseconds squared and reported in natural log scale. Associations between police work stressors and vagal control were examined using linear regression for significance testing and analysis of covariance for descriptive purposes, stratified by gender, and adjusted for age and race/ethnicity.

Results: There were no significant associations between police work stressor exposure indices and vagal control among men. Among women, the inverse associations between the *lack of support* stressor exposure and vagal control were statistically significant in adjusted models for indices of exposure over the past year (lowest stressor quartile: $M = 5.57$, 95% CI 5.07 to 6.08,

Correspondence Michael E. Andrew, Ph.D., Biostatistics and Epidemiology Branch, Health Effects Laboratory Division, National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention, 1095 Willowdale Road, Morgantown, WV 26505., mandrew@CDC.gov.

CONTRIBUTORS

MA was involved in conception and design, literature review, procuring funding, data analysis, data interpretation, and drafted and revised the manuscript; JV was involved in conception and design, managed data acquisition, and performed revision of the manuscript; JG, DF, AM, and SL were involved in data analysis, data interpretation, and revision of the manuscript; LC and TH were involved in conception and design, data interpretation and revision of the manuscript; DM was involved in conception and design, data interpretation and performed revision of the manuscript; CB was involved in conception and design, procuring funding, data interpretation, and revision of the manuscript. All contributors participated in final approval of the manuscript.

and highest stressor quartile: *M* = 5.02, 95% CI 4.54 to 5.51, test of association from continuous linear regression of vagal control on *lack of support* stressor β = −273, *P* =.04).

Conclusions: This study supports an inverse association between lack of organizational support and vagal control among female but not male police officers.

1 | INTRODUCTION

This study examines the relationships between exposure to police work stressors and cardiac vagal control (Chambers & Allen, 2007), estimated by the high frequency (HF) component of resting heart rate variability (HRV). The loss of vagal control is believed to be a significant and specific marker of dysfunction in the system that allows individuals to return to normal levels of physiological arousal after exposure to a stressor (Porges, 1995, 2007; Thayer & Brosschot, 2005; Thayer & Lane, 2000; Thayer & Sternberg, 2006). This dysfunction in the stress response system may be brought about by a number of factors, particularly conditions with chronic or repeated exposure to highly intense stressors (McEwen, 1998; McEwen & Lasley, 2002). Police work produces these conditions. Police officers (861,000 in the United States) are exposed to physical harm, shift work, long work hours, administrative organizational stressors, varying levels of organizational support, victims of violence, police suicide, and other tragic events. Furthermore, lower vagal control has been associated with increased levels of psychological distress, chronic inflammation, cardiovascular disease (CVD), and metabolic disorders. It is also thought to provide a link between stress, psychological disorders, and the development of CVD (Andrew et al., 2013; Carnethon et al., 2006; Collins, Karasek, & Costas, 2005; Dekker et al., 2000; Sloan et al., 2007; Thayer, Friedman, & Borkovec, 1996; Thayer & Lane, 2007; Thayer, Yamamoto, & Brosschot, 2010; Zucker, Samuelson, Muench, Greenberg, & Gevirtz, 2009). A compromise in vagal control due to police work may be a contributing factor to the increased morbidity and mortality from CVD in this occupation (Zimmerman, 2012).

The autonomic nervous system plays an important role in the development of stress related psychological disorders and CVD (Porges, 1995, 2007; Thayer & Brosschot, 2005; Thayer & Lane, 2000; Thayer & Sternberg, 2006; Thayer et al., 2010). Current thinking about vagal control and disease is broadly represented in three integrative theories related to human adaptation: (1) Polyvagal theory, which moves vagal control beyond the realm of cardiac control to include general human adaptation to environmental challenge, and provides a theoretical structure for interpreting observations that vagal control is a marker of the ability to perceive and manage environmental challenges through social engagement (Porges, 2007); (2) The neurovisceral integration theory of emotional regulation and dysregulation, which provides a theoretical framework and evidence supporting the idea that cardiac vagal conrol is a marker for functioning of prefrontal inhibitory control of subcortical systems involved in facilitating emotional, cognitive, and physiological self-regulation in response to environmental challenges (Park & Thayer, 2014; Thayer & Brosschot, 2005; Thayer & Fischer, 2009; Thayer et al., 1996, 2010; Thayer & Lane, 2000, 2007; Thayer & Siegle, 2002; Thayer & Sternberg, 2006), and (3) Allostasis theory, which asserts that allostatic load or “wear and tear” on adaptive systems, incorporating both psychological and biological processes, defines chronic stress adaptation which predisposes toward mental and physical dysfunction. Allostasis theory identifies the hormonal and neurological processes (e.g., vagal control) involved as well as long-term health effects (McEwen & Lasley, 2002; McEwen, 1998; McEwen & Wingfield, 2003). Regarding the general details of allostatic systems and allostatic load, McEwen and Gianaros (2011) state the following:

> The active process of responding to a challenge to the body by triggering chemical mediators of adaptation (HPA, autonomic, metabolic, immune) that operate in a nonlinear network. Allostasis is essential for maintaining homeostasis in the face of challenges or demands imposed by changes in (a) the environment and (b) an individual's behavioral state that are registered by the brain.

Further they state,

> Allostatic systems enable the individual to cope with stressful experiences. They are adaptive when rapidly mobilized and terminated. However, when the activity of allostatic systems is sluggish, ineffective, prolonged, or not terminated promptly, allostatic systems can impair mental and physical health through their maladaptive effects on brain plasticity and metabolic, immune, and cardiovascular pathophysiology (allostatic load).

The allostasis model then provides a general explanation of how "ineffective, prolonged, or not terminated" functioning of the autonomic nervous system from long-term exposure to workplace stressors may lead to autonomic dysregulation.

It is thought that autonomic dysregulation as measured by vagal control may provide a unifying framework for investigating the impact of psychosocial risk factors and work related stress on CVD, and that autonomic dysregulation may be part of a causal pathway from work stress to CVD (Chandola, Heraclides, & Kumari, 2010; Jarczok et al., 2013; Thayer & Lane, 2007; Thayer & Sternberg, 2006; Thayer et al., 2010). More specifically, the observation that certain risk factors lead to lower levels of vagal control is thought to be a reflection of dysregulation in prefrontal inhibitory regulation of subcortical arousal systems (Thayer & Lane, 2007), and one explanation of how this dysregulation may come about is through allostatic load (McEwen & Gianaros, 2011). The first step in examining this idea in police officers is to examine possible associations between police work stressors and vagal control.

2 | METHODS

2.1 | Study design and participants

The data used in this study come from the Buffalo Cardio-Metabolic Occupational Police Stress (BCOPS) study. The BCOPS study is an ongoing collaboration between the National Institute for Occupational Safety and Health, and the University at Buffalo, The State University of New York. The study design and population reported here consists of a cross-sectional examination for 464 officers from May 2004 to October 2009. During recruitment the eligible target population of officers employed by the Buffalo, New York, Police Department, who were invited to participate, decreased from 710 in 2004 to 635 in 2007.

Of the 464 participating officers examined during this time, 17 had missing electrocardiogram (ECG) data, 57 had evidence or medical history of irregular heart rate, 22 had retired at the time of the examination, and 22 had incomplete stress exposure data. These 118 participants were excluded leaving 346 who had complete data to assess HRV and stress exposure. All participants provided signed written consent. Human subjects review board oversight is described in a previous paper (Violanti et al., 2006).

2.2 | Clinic examination

All measurement for the BCOPS clinic examination reported here were obtained on the same day for each participant. Participants were instructed to avoid the following after 10:00 PM on the night before the day of examination: eating or drinking anything but water, strenuous physical exercise, caffeinated beverages, alcoholic beverages, and use of tobacco. All officers were given a standardized breakfast around 8:30 AM after the fasting blood draw and before other study components.

2.3 | Spielberger police stress survey

The Spielberger Police Stress Survey consists of 60 items that measure a self-reported stress rating and frequency of occurrence for items describing events or conditions applicable and relatively prevalent in police work (eg, “Making arrests while alone”). The officer gives each item a stress intensity rating from 0 to 100 where the higher the score the more stressful the situation described in the item (Martelli, Waters, & Martelli, 1989; Spielberger, Westberry, Grier, & Greenfield, 1981). Each item also provides check boxes for the number of times the event or condition has occurred in the past month (0, 1, 2, 3–5, 6–9, 10+) and in the past year (0, 1, 2–5, 6–10, 11–24, 25+). Using these item scores, a total stress score is calculated by multiplying the subjective stress rating times the value of the frequency categories or midpoint (for ranges) for the past year or the past month if a score that represents only recent events is needed, and then summing these products over all 60 items. Sub-indices can be obtained for *administrative* stressors, *lack of support* stressors, and *physical or psychological danger* stressors by summing the product of stress rating and frequency for items indicated for relevant subsets of survey items. The sub-index scores mentioned above are used to assess the separate influence of *administrative* stressors, *lack of support* stressors, and *physical or psychological danger* stressors.

2.4 | Heart rate variability measurements

ECG measurements were used to obtain HRV, and were measured and processed according to standard methods published by the Task Force of the European Society of Cardiology and the North American Society of Pacing Electrophysiology (Camm et al., 1996). ECG measurements were obtained from a lead II voltage time series during the resting carotid ultrasound examination. ECG voltages were sampled at 2000 Hz and digitally captured using the Biopac Systems, Inc. MP100 system/software with accompanying ECG Amplifier (C series), appropriate ECG leads, cables, electrodes, and computer for recording and data processing. Officers were supine and resting for five minutes before ECG data for HRV analyses were recorded. The time of day for the ECG examination varies from 9:15 AM to around 12:00 PM depending on officer placement in the clinic schedule.

Resting ECG time series were extracted from the first five minutes of examination, and processed using an automated data adaptive QRS (Q wave-R-wave-S wave sequence characteristic of normal ECG data) detection package that inserts a marker at each proposed R wave (gBSanalyze advanced biosignal processing system with ECG toolbox, Guger Technologies, Graz, Austria, www.gtec.at).

A QRS interval-clustering step created clusters of QRS intervals within a participant's ECG record based on how well the QRS intervals correlated with each other. Atypical QRS intervals as well as noise or movement artifacts are thus identified, allowing special handling during data editing. The last step includes visual inspection of the ECG overlaid with QRS markers and hand editing of R wave markers: for example, removal of markers not located on R waves, addition of markers that were not detected by software, and identification of markers for deletion of isolated ectopic beats (Lippman, Stein, & Lerman, 1994). Visual identification of ectopic beats was validated using several versions of an impulse rejection filter (McNames, Thong, & Aboy, 2004). Generally, data from participants had no or very few isolated ectopic beats, and were easily identified. ECGs having a large number of ectopic beats or irregular QRS intervals led to exclusion of the participant from data analyses.

Frequency domain methods are recommended for short-term stationary measurements of HRV. This is because theoretical and physiological interpretations of the HF component are conceptually well grounded (Camm et al., 1996). Accordingly, for each officer R-to-R interval time series were processed using the R statistical computer programming language by cubic spline interpolation to provide a series with equal sample increments at two samples per second. The interpolated time series was detrended using a smoothness priors method (Tarvainen, Ranta-Aho, & Karjalainen, 2002). This produces equally spaced mean-zero time series data with no long-term trends, thus meeting assumptions of spectral analysis models. Next, data were processed using a parametric autoregressive spectral analysis of order 16 (Boardman, Schlindwein, Rocha, & Leite, 2002). The HF component of HRV, used to estimate vagal control, was defined as the area under the power spectral density from 0.15 to 0.4 Hz and was calculated for each participant. All results for HF HRV (ie, vagal control) were reported in natural log scale.

2.5 | Statistical analyses

Associations between continuous police stressor exposure indices and cardiac vagal control were modeled using linear regression with each police work stressor index as the independent variable and vagal control as the dependent variable. The association for each police work stressor index with vagal control was analyzed in a separate regression model. These relationships were described by examining mean vagal control values across quartiles of the stressor exposure indices, as well as by regression coefficients. Regression coefficients and reported significance levels are from regression models using the continuous stress exposure indices after transforming them to *z* scores. This transformation helps with interpretation as the stress indices are not in simple units. The regression coefficients can then be interpreted as the amount of change in the natural log of vagal control for one standard deviation increase in stressor index. Associations were reported as unadjusted, age-adjusted and as age- and race-adjusted. Covariates for inclusion in adjusted models were selected based on review of literature on vagal control and on analysis of bivariate associations between each covariate and the exposure variable (police work stressors) and outcome variable (vagal control) in these analyses. Covariates examined included age, race/ethnicity, and smoking status. The final decision to adjust for a covariate was made based on each covariate's effect after adjustment on the association of interest. Both age and race were included based on the above criteria. All analyses were stratified by gender because of significant effect modification by gender determined by additive statistical interaction tests for gender by exposure ($P < .05$) for two of the three stress exposure indices, *administrative* stressors and *lack of support* stressors (see Table 3–5 footnotes for *P*-values). All statistical tests were two-tailed and performed using significance level $\alpha = 0.05$.

3 | RESULTS

The demographic and lifestyle characteristics of this study are summarized in Table 1. Associations between vagal control and potential covariates are presented in Table 2. Mean vagal control was significantly higher ($P = .002$) among women (5.28 ± 1.14) than among men (4.86 ± 1.10). It is interesting to note that age is only associated with vagal control among men (men: $P < .001$, women: $P = .828$). The observed significant association of years of service and also rank with vagal control among men is explained by the age difference across years of service and rank. Men who report never smoking have higher vagal control than those who are current smokers and former smokers ($P = .008$) while there is no association among women ($P = .6$).

Age and race were the only covariates having influence on the associations between exposure to police stressors and vagal control reported in Tables 3–5, therefore age and race adjusted models are presented therein. There were no significant associations between any of the police stressor exposure indices and vagal control among men ($P > .05$). For women, the *administrative* stressor index was significant in the unadjusted ($\beta = -0.278$, $P = .024$), and age adjusted ($\beta = -0.277$, $P = .025$) models, but not significant after adjusting for race and age ($\beta = -0.225$, $P = .086$) (Table 3). Among women there was no association between the *physical or psychological danger* stressor index and vagal control ($\beta = -0.087$, $P = .497$) (Table 4). Associations between the *lack of support* stressor index and vagal control were statistically significant (Table 5) in both unadjusted ($\beta = -0.314$, $P = .017$) and adjusted models ($\beta = -0.273$, $P = .044$).

4 | DISCUSSION

Associations between police-work stressors and vagal control among both women and men were expected, so having an association among women only, and for the *lack of support* stressor only was unexpected. To understand this result, it is helpful to first examine the finding that women have higher mean vagal control when compared to men. The mean difference in vagal control between women and men has been observed in many other studies (Koenig & Thayer, 2016), and this difference has been shown to attenuate after menopause (Liu, Kuo, & Yang, 2003). It is thought that higher vagal control among women may be related to differences in the way women cope with stressors, specifically through higher vagally mediated parasympathetic function. As Koenig and Thayer (2016) point out in their ground-breaking meta-analysis of sex differences in HRV, these differences appear to include the effects of sex hormones, oxytocin, and brain structures involved in managing stress arousal and emotional regulation. As these differences point in the direction of women potentially having higher biological capacity for social engagement and using social support for coping with stressful events, they are thought to be consistent with a model for stress coping known as the tend- and-befriend model (Koenig & Thayer, 2016). The tend-and befriend model posits that women may rely on social engagement for responding to stressors to a greater degree than men, and functioning of oxytocin systems have been implicated in this (Taylor, 2006; Taylor et al., 2000).

Men and women may cope with exposure to stressors in different ways. In a meta-analytic review of literature on sex differences in coping, Tamres, Janicki, and Helgeson (2002) found that women rely more heavily on support behaviors for coping with stress when compared to men. As mentioned above, it is also thought that the observation that women have higher vagal control than men may be explained by the tend-and-befriend model of stress. In the present study, women who reported experiencing a greater lack of organizational support had lower vagal control when compared to women who reported lower levels of this stressor. This trend was not found in male police officers. Therefore, female officers who have lower levels of the *lack of support* stressor appear to retain the expected higher levels of vagal control, while female officers among the highest quartile of the *lack of support* stressor have levels of vagal control similar to those of male officers. Chronic *lack of support* may then be associated with loss of a protective advantage for cardiovascular risk in female officers. This result is also consistent with other analyses examining associations between exposure to police stressors and a subclinical CVD marker in this study population. Hartley et al. (2011) found that *administrative* and *lack of support* stressors were associated with metabolic syndrome in women but not men.

One explanation for this result is that organizational influences may chronically thwart attempts by female officers to engage in support coping, possibly leading to repeated attempts to engage in support coping that do not lead to resolution of the original stressor, rather engaging a second stressor related to *lack of support*. Consistent with the theory of allostasis (McEwen & Lasley, 2002), this may lead to allostatic load and consequent dysregulation of the ability to control the biological response to stressors through parasympathetic braking. A potential biological interpretation for this dysregulation in parasympathetic control points to changes in systems related to oxytocin and regulation of affiliative ways of managing behaviors for responding to stressors. Oxytocin and related systems are known to be involved in regulation of the autonomic nervous system through downregulation of the sympathetic nervous system and enhancing parasympathetic function, and differences in these systems’ response to stressors have been noted between men and women (Carter, 2014; Porges, 2011). Taylor (2006) reviewed experimental findings among women showing that, under the influence of a stressor, when efforts to mobilize affiliative support are thwarted then higher levels of the stress response can occur, and that this may be more pronounced in individuals with higher levels of oxytocin activity and concomitant attunement to social aspects of the environment. Thus, chronic exposure to lack of organizational support may produce conditions of heightened, prolonged, and improperly terminated stress response. These conditions are consistent with the conditions that allostasis theory states may lead to allostatic load, specifically dysregulation in oxytocin systems' responsivity, and related changes in vagal control.

Limitations of this study include the cross-sectional design, which prevents making causal inferences. For this reason, it is not possible to know if lower levels of organizational support lead to decreased vagal control, or if individuals with lower vagal control, tend to be less effective in engaging with opportunities for organizational support, while also reporting higher frequency and perceived stress of related failures to engage. However, if the latter were the case we might expect to find the association in both men and women. Also, analyses using only the mean of reported frequencies of workplace items from the *lack of support* index, without multiplying by the subjective rating (data not shown), indicated that the mean stressor frequency is associated with vagal control. Another limitation for the gender stratified analyses is lower sample size, particularly among female participants, which limits power to detect associations. This limitation was overcome by analyzing data using the continuous stressor indices and vagal control in linear regression analyses.

Among the forms of lack of organizational support included in the summary measure used in this study are the following: inadequate support by the supervisor, poor, or inadequate supervision, difficulty getting along with supervisors, inadequate support by the department, poor, or inadequate supervision, assignment of incompatible partner, fellow officers not doing their job, and inadequate or poor quality equipment. While these conditions may be found in any workplace, they may also be open to some modification through training of supervisors and employees, and possible changes in organizational practices. The number of women in policing is growing and these officers experience a variety of stressors related to working in a male-dominated work-place (Elliot, Garg, Kuehl, DeFrancesco, & Sleigh, 2015; Hartley, Mnatsakanova, Burchfiel, & Violanti, 2014). In this study, we see that among police women only, exposure to a stressor related to lack of organizational support has a unique association with a marker for the regulation of stress, while the danger inherent in police-work does not. While the danger in police-work may be difficult to modify, organizational practices might be open to modification.

5 | CONCLUSION

In our study, exposure to lack of organizational support is associated with reduced vagal control among police women, but not men. As some aspects of organizational support may be modifiable, these results point to an area for potential intervention to improve health and performance in police officers.

ACKNOWLEDGMENTS

The authors thank the staff at the BCOPS Study field center at SUNY Buffalo for providing excellent officer recruitment and retention, and high quality data collection, management and documentation. Michael Kashon is gratefully acknowledged for several careful readings and suggested revisions of the manuscript.

Funding information

Contract sponsor: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health extramural funding; Contract number: 200-2003-01580.

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

LITERATURE CITED

Andrew ME, Li SQ, Wactawski-Wende J, Dorn JP, Mnatsa-kanova A, Charles LE, … Sharp DS (2013). Adiposity, muscle, and physical activity: Predictors of perturbations in heart rate variability. American Journal of Human Biology, 25, 370– 377. [PubMed: 23564378]

Boardman A, Schlindwein FS, Rocha AP, & Leite A (2002). A study on the optimum order of autoregressive models for heart rate variability. Physiological Measurement, 23, 325–336. [PubMed: 12051304]

Camm AJ, Malik M, Bigger JT, Breithardt G, Cerutti S, Cohen RJ, … Singer D (1996). Heart rate variability - Standards of measurement, physiological interpretation, and clinical use. Circulation, 93, 1043–1065. [PubMed: 8598068]

Carnethon MR, Prineas RJ, Temprosa M, Zhang ZM, Uwaifo G, & Molitch ME (2006). The association among autonomic nervous system function, incident diabetes, and intervention arm in the Diabetes Prevention Program. Diabetes Care, 29, 914–919. [PubMed: 16567837]

Carter CS (2014). Oxytocin pathways and the evolution of human behavior. Annuals Review of Psychology, 65, 17–39.

Chambers AS, & Allen JJB (2007). Cardiac vagal control, emotion, psychopathology, and health. Biological Psychology, 74, 113–115. [PubMed: 17055143]

Chandola T, Heraclides A, & Kumari M (2010). Psychophysiological biomarkers of workplace stressors. Neuroscience and Biobehavioral Reviews, 35, 51–57. [PubMed: 19914288]

Collins SM, Karasek RA, & Costas K (2005). Job strain and autonomic indices of cardiovascular disease risk. American Journal of Industrial Medicine, 48, 182–193. [PubMed: 16094616]

Dekker JM, Crow RS, Folsom AR, Hannan PJ, Liao D, Swenne CA, & Schouten EG (2000). Low heart rate variability in a 2-minute rhythm strip predicts risk of coronary heart disease and mortality from several causes: the ARIC Study. Atherosclerosis Risk In Communities. Circulation, 102, 1239–1244. [PubMed: 10982537]

Elliot D, Garg B, Kuehl K, DeFrancesco C, & Sleigh A (2015). Why are women law enforcement officers more burned-out and what might help them? Occupation Medicine and Health Affairs, 3, 1–9.

Hartley TA, Burchfiel CM, Fekedulegn D, Andrew ME, Knox SS, & Violanti JM (2011). Associations between police officer stress and the metabolic syndrome. International Journal of Emergency Mental Health, 13, 243–256. [PubMed: 22900458]

Hartley TA, Mnatsakanova A, Burchfiel CM & Violanti JM (2014). Stressors and associated health effects for women police officers. In Violanti JM (Ed.), Dying for the job: Police work exposure and health (pp. 93–114). Springfield, Ill: Charles C Thomas.

Jarczok MN, Jarczok M, Mauss D, Koenig J, Li J, Herr RM, & Thayer JF (2013). Autonomic nervous system activity and workplace stressors–a systematic review. Neuroscience and Biobehavioral Reviews, 37, 1810–1823. [PubMed: 23891906]

Koenig J, & Thayer JF (2016). Sex Differences in Healthy Human Heart Rate Variability: A Meta-Analysis. Neuroscience and Biobehavioral Reviews, 64, 288–310. [PubMed: 26964804]

Lippman N, Stein KM, & Lerman BB (1994). Comparison of methods for removal of ectopy in measurement of heart rate variability. American Journal of Physiology, 267, H411–H418. [PubMed: 7519408]

Liu CC, Kuo TBJ, & Yang CCH (2003). Effects of estrogen on gender-related autonomic differences in humans. American Journal of Physiology-Heart and Circulatory Physiology, 285, H2188–H2193. [PubMed: 12881217]

Martelli TA, Waters LK, & Martelli J (1989). The police stress survey: reliability and relation to job satisfaction and organizational commitment. Psychological Reports, 64, 267–273. [PubMed: 2928440]

McEwen BS (1998). Protective and damaging effects of stress mediators. New England Journal of Medicine, 338, 171–179. [PubMed: 9428819]

McEwen BS, & Gianaros PJ (2011). Stress- and allostasis-induced brain plasticity. Annual Review of Medicine, 62, 431–445.

McEwen B, & Lasley EN (2002). The end of stress as we know it Washington, DC: John Henry Press.

McEwen BS, & Wingfield JC (2003). The concept of allostasis in biology and biomedicine. Hormones and Behavior, 43, 2–15. [PubMed: 12614627]

McNames J, Thong T, & Aboy M (2004). Impulse rejection filter for artifact removal in spectral analysis of biomedical signals. Conference Proceedings IEEE Engineering in Medicine and Biology Society, 1, 145–148.

Park G, & Thayer JF (2014). From the heart to the mind: cardiac vagal tone modulates top-down and bottom-up visual perception and attention to emotional stimuli. Frontiers in Psychology, 5, 1–8. [PubMed: 24474945]

Porges SW (1995). Cardiac vagal tone: a physiological index of stress. Neuroscience and Biobehavioral Reviews, 19, 225–233. [PubMed: 7630578]

Porges SW (2007). The polyvagal perspective. Biological Psychology, 74, 116–143. [PubMed: 17049418]

Porges SW (2011). *The polyvagal theory: Neurophysiological foundations of emotions, attachment, communication, and self-regulation* (347 p). In Schore AN (Ed.), New York: Norton.

Sloan RP, McCreath H, Tracey KJ, Sidney S, Liu K, & See-man T (2007). RR interval variability is inversely related to inflammatory markers: the CARDIA study. Molecular Medicine, 13, 178–184. [PubMed: 17592552]

Spielberger CD, Westberry LG, Grier KS, & Greenfield G (1981). The police stress survey: Sources of stress in law enforcement (Human Resources Institute Monograph Series Three, No. 6) Tampa, FL: University of South Florida, College of Social and Behavioral Sciences.

Tamres LK, Janicki D, & Helgeson VS (2002). Sex differences in coping behavior: A meta-analytic review and an examination of relative coping. Personality and Social Psychology Review, 6, 29.

Tarvainen MP, Ranta-Aho PO, & Karjalainen PA (2002). An advanced detrending method with application to HRV analysis. IEEE Transactions on Biomedical Engineering, 49, 172–175. [PubMed: 12066885]

Taylor SE (2006). Tend and befriend biobehavioral bases of affiliation under stress. Current Directions in Psychological Science, 15, 273–277.

Taylor SE, Klein LC, Lewis BP, Gruenewald TL, Gurung RA, & Updegraff JA (2000). Biobehavioral responses to stress in females: tend-and-befriend, not fight-or-flight. Psychological Review, 107, 411–429. [PubMed: 10941275]

Thayer JF, & Brosschot JF (2005). Psychosomatics and psychopathology: looking up and down from the brain. Psychoneuroendocrinology, 30, 1050–1058. [PubMed: 16005156]

Thayer JF, & Fischer JE (2009). Heart rate variability, overnight urinary norepinephrine and C-reactive protein: evidence for the cholinergic anti-inflammatory pathway in healthy human adults. Journal of Internal Medicine, 265, 439–447. [PubMed: 19019182]

Thayer JF, Friedman BH, & Borkovec TD (1996). Autonomic characteristics of generalized anxiety disorder and worry. Biological Psychiatry, 39, 255–266. [PubMed: 8645772]

Thayer JF, & Lane RD (2000). A model of neurovisceral integration in emotion regulation and dysregulation. Journal of Affective Disorders, 61, 201–216. [PubMed: 11163422]

Thayer JF, & Lane RD (2007). The role of vagal function in the risk for cardiovascular disease and mortality. Biological Psychology, 74, 224–242. [PubMed: 17182165]

Thayer JF, & Siegle GJ (2002). Neurovisceral integration in cardiac and emotional regulation. IEEE Engineering in Medicine and Biology Magazine, 21, 24–29. [PubMed: 12222113]

Thayer JF, & Sternberg E (2006). Beyond heart rate variability: vagal regulation of allostatic systems. Annals of the New York Academy of Sciences, 1088, 361–372. [PubMed: 17192580]

Thayer JF, Yamamoto SS, & Brosschot JF (2010). The relationship of autonomic imbalance, heart rate variability and cardiovascular disease risk factors. International Journal of Cardiology, 141, 122–131. [PubMed: 19910061]

Violanti JM, Burchfiel CM, Miller DB, Andrew ME, Dorn J, Wactawski-Wende J, … Trevisan M (2006). The Buffalo Cardio-Metabolic Occupational Police Stress (BCOPS) pilot study: methods and participant characteristics. Annals of Epidemiology, 16, 148–156. [PubMed: 16165369]

Zimmerman FH (2012). Cardiovascular disease and risk factors in law enforcement personnel: a comprehensive review. Cardiology in Review, 20, 159–166. [PubMed: 22314143]

Zucker TL, Samuelson KW, Muench F, Greenberg MA, & Gevirtz RN (2009). The effects of respiratory sinus arrhythmia biofeedback on heart rate variability and posttraumatic stress disorder symptoms: a pilot study. Applied Psychophysiology and Biofeedback, 34, 135–143. [PubMed: 19396540]

TABLE 1

Demographic and lifestyle characteristics by gender

Characteristic or Measure	Men (*N* = 59)		Women (*N* = 87)	
	N	**Mean (SD) or %**	***N***	**Mean (SD) or %**
Age	259	41.2 (6.8)	87	40.7 (5.5)
Age Group				
<40 years	111	42.9	36	41.4
40–49 years	112	43.2	45	51.7
50 + years	36	13.9	6	6.9
Ethnicity				
White	203	80.2	63	72.4
African american	43	17.0	24	27.6
Hispanic	7	2.8	0	0.0
Marital Status				
Single	23	9.0	17	19.5
Married	198	77.3	54	62.1
Divorced	35	13.7	16	18.4
Years of Police Service				
1–5 years	21	8.2	6	6.9
6–10 years	62	24.1	29	33.3
11–15 years	51	19.8	10	11.5
16–20 years	64	24.9	25	28.7
20+ years	59	23.0	17	19.5
Rank				
Police Officer	176	70.1	67	77.0
Sergeant/Lieutenant	37	14.7	10	11.5
Capt./Detect./Chief	38	15.1	10	11.5
Smoking Status				
Current	34	13.2	20	23.5
Former	51	19.8	24	28.2
Never	172	66.9	41	48.2

The Buffalo Cardio-Metabolic Occupational Police Stress (BCOPS) Study, 2004–2009.

TABLE 2

Mean vagal control (in units of natural log of high frequency HRV) by demographic and lifestyle characteristics; BCOPS Study, 2004–2009

	Vagal control (Ln (HF))			
	Men		Women	
	Mean (SD)	*P*-value	Mean (SD)	*P*-value
Age Group				
<40 years	5.23 (1.07)	<.001[*]	5.20 (1.03)	.828[*]
40–49 years	4.71 (0.99)		5.37 (1.22)	
50 + years	4.13 (1.07)		5.09 (1.27)	
Gender	4.86 (1.10)		5.28 (1.14)	.002[a]
Ethnicity				
White	4.80 (1.11)	.357[+]	5.14 (1.20)	.068[+]
Black	5.06 (1.10)		5.64 (0.87)	
Hispanic	4.74 (0.89)		–	
Marital Status				
Single	5.26 (1.08)	.091[+]	5.47 (1.19)	.402[+]
Married	4.84 (1.10)		5.15 (1.21)	
Divorced	4.61 (1.06)		5.52 (0.79)	
Years of Police Service				
1–5 years	5.32 (0.78)	<.001[*]	4.49 (1.31)	.933[*]
6–10 years	5.20 (0.95)		5.35 (0.92)	
11–15 years	5.02 (1.22)		5.40 (0.97)	
16–20 years	4.61 (1.09)		5.64 (1.13)	
20 + years	4.42 (1.04)		4.84 (1.36)	
Rank				
Police Officer	4.97 (1.06)	.017[+]	5.31 (1.05)	.294[+]
Sergeant/Lieutenant	4.42 (0.98)		5.55 (1.42)	
Captain/Detective/Chief/Commissioner	4.77 (1.13)		4.79 (1.37)	
Smoking Status				
Current	4.71 (0.92)	.008[+]	5.15 (0.96)	.605[+]

	Vagal control (Ln (HF))			
	Men		**Women**	
	Mean (SD)	***P*-value**	**Mean (SD)**	***P*-value**
Former	4.46 (1.15)		5.45 (1.05)	
Never	4.99 (1.09)		5.19 (1.26)	

* *P*-values for the linear trend across levels of demographic variable within each gender group.

+ *P*-values for test of difference across categories of demographic variable.

[a] Contrast between men and women across row of table.

TABLE 3

Unadjusted and adjusted mean vagal control (in units of natural log of high frequency HRV) by quartiles of Spielberger police stress administrative index for the past year; BCOPS Study, 2004–2009

Spielberger Police Stress Administrative Index, past year	Unadjusted			Age-Adjusted			Age-and Race-Adjusted		
	N	Mean (95% CI)	*P*-value*	*N*	Mean (95% CI)	*P*-value*	*N*	Mean (95% CI)	*P*-value*
Women									
Quartile 1 (0–89.9)	21	5.87 (5.34, 6.35)		21	5.89 (5.40, 6.39)		21	5.82 (5.30, 6.35)	
Quartile 2 (90.0–245.9)	22	5.22 (4.75, 5.69)		22	5.21 (4.74, 5.68)		22	5.21 (4.74, 5.69)	
Quartile 3 (246.0–459.9)	22	4.98 (4.51, 5.45)		22	4.96 (4.50, 5.44)		22	4.99 (4.51, 5.47)	
Quartile 4 (460.0–1130.0)	22	5.08 (4.61, 5.55)		22	5.07 (4.60, 5.55)		22	5.12 (4.63, 5.60)	
β (SE)[a]	87	−0.278 (0.120)	**.024**	87	−0.277 (0.121)	**.025**	87	−0.225 (0.130)	.086
Men									
Quartile 1 (0–108.1)	64	4.95 (4.67, 5.22)		64	4.99 (4.74, 5.24)		62	4.97 (4.71, 5.23)	
Quartile 2 (108.2–262.9)	65	4.75 (4.48, 5.01)		65	4.77 (4.52, 5.02)		63	4.77 (4.51, 5.02)	
Quartile 3 (263.0–504.9)	65	4.68 (4.42, 4.95)		65	4.70 (4.45, 4.95)		63	4.68 (4.42, 4.93)	
Quartile 4 (505.0–1619.2)	64	5.04 (4.77, 5.31)		64	4.95 (4.70, 5.20)		64	4.95 (4.70, 5.21)	
β (SE)[a]	258	0.077 (0.068)	.258	258	0.036 (0.064)	.572	252	0.040 (0.065)	.534

*The *P*-values are for the linear trend estimates with continuous stress index values.

[a]Each regression coefficient (β) can be interpreted as β units change in the natural log of high frequency HRV (ms^2) for each increase of one standard deviation in the given police stress index.

TABLE 4

Unadjusted and adjusted mean vagal control (in units of natural log of high frequency HRV) by quartiles of Spielberger police stress physical/psychological threat index for the past year; BCOPS Study, 2004–2009

Spielberger Police Stress Physical/Psychological Threat Index, past year	Unadjusted			Age-Adjusted			Age-and Race-Adjusted		
	N	Mean (95% CI)	*P*-value*	*N*	Mean (95% CI)	*P*-value*	*N*	Mean (95% CI)	*P*-value*
Women									
Quartile 1 (0–79.9)	21	5.57 (5.07, 6.06)		21	5.57 (5.06, 6.07)		21	5.45 (4.93, 5.97)	
Quartile 2 (80.0–269.9)	22	5.17 (4.69, 5.66)		22	5.17 (4.68, 5.66)		22	5.12 (4.64, 5.62)	
Quartile 3 (270.0–439.9)	22	5.26 (4.78, 5.75)		22	5.26 (4.77, 5.75)		22	5.37 (4.87, 5.88)	
Quartile 4 (440.0–1046.6)	22	5.13 (4.65, 5.62)		22	5.13 (4.65, 5.62)		22	5.18 (4.69, 5.67)	
β (SE)[a]	87	20.152 (0.121)	.213	87	20.151 (0.122)	.218	87	20.087 (0.128)	.497
Men									
Quartile 1 (0–96.1)	64	4.80 (4.53, 5.08)		64	4.91 (4.66, 5.17)		62	4.90 (4.63, 5.16)	
Quartile 2 (96.2–220.9)	65	4.78 (4.51, 5.05)		65	4.82 (4.60, 5.07)		63	4.81 (4.55, 5.07)	
Quartile 3 (221.0–429.9)	65	4.81 (4.54, 5.08)		65	4.80 (4.55, 5.05)		64	4.80 (4.55, 5.06)	
Quartile 4 (430.0–1197.9)	64	5.04 (4.77, 5.31)		64	4.89 (4.64, 5.15)		63	4.88 (4.62, 5.14)	
β (SE)[a]	258	0.096 (0.069)	.163	258	0.025 (0.065)	.705	252	0.027 (0.066)	.678

* The *P*-values are for the linear trend estimates with continuous stress index values.

[a] Each regression coefficient (β) can be interpreted as β units change in the natural log of high frequency HRV (ms^2) for each increase of one standard deviation in the given police stress index.

TABLE 5

Unadjusted and adjusted mean vagal control (in units of natural log of high frequency HRV) by quartiles of Spielberger police stress lack of support index for the past year; BCOPS Study, 2004–2009

Spielberger Police stress Lack of Support Index, past year	Unadjusted			Age-Adjusted			Age-and Race-Adjusted		
	N	Mean (95% CI)	*P*-value*	*N*	Mean (95% CI)	*P*-value*	*N*	Mean (95% CI)	*P*-value*
Women									
Quartile 1 (0–76.9)	21	5.65 (5.16, 6.14)		21	5.65 (5.15, 6.14)		21	5.57 (5.07, 6.08)	
Quartile 2 (77.0–169.9)	22	5.35 (4.87, 5.83)		22	5.35 (4.85, 5.84)		22	5.33 (4.84, 5.82)	
Quartile 3 (170.0–364.9)	22	5.17 (4.69, 5.65)		22	5.17 (4.68, 5.66)		22	5.20 (4.71, 5.69)	
Quartile 4 (365.0–921.2)	22	4.98 (4.50, 5.46)		22	4.97 (4.49, 5.46)		22	5.02 (4.54, 5.51)	
β (SE)[a]	87	−0.314 (0.128)	**.017**	87	−0.315 (0.130)	**.018**	87	−0.273 (0.133)	**.044**
Men									
Quartile 1 (0–67.5)	64	4.95 (4.68, 5.22)		64	4.95 (4.70, 5.20)		62	4.91 (4.65, 5.17)	
Quartile 2 (67.6–195.9)	65	4.78 (4.51, 5.05)		65	4.74 (4.49, 4.99)		63	4.75 (4.49, 5.01)	
Quartile 3 (196.0–389.9)	65	4.86 (4.59, 5.13)		65	4.82 (4.57, 5.07)		63	4.81 (4.54, 5.06)	
Quartile 4 (390.0–1547.7)	64	4.83 (4.56, 5.10)		64	4.91 (4.66, 5.17)		65	4.91 (4.65, 5.16)	
β (SE)[a]	258	−0.021 (0.067)	.756	258	−0.023 (0.063)	.710	252	−0.025 (0.064)	0.692

[*] The *P*-values are for the linear trend estimates with continuous stress index values.

[a] Each regression coefficient (β) can be interpreted as β units change in the natural log of high frequency HRV (ms^2) for each increase of one standard deviation in the given police stress index.