The author(s) shown below used Federal funding provided by the U.S. Department of Justice to prepare the following resource:

Document Title:	**Atypical Work Hours and Adaptation in Law Enforcement: Targets for Disease Prevention**
Author(s):	**John M. Violanti, James B. Burch, Jonathon Jacobs, Jonathan L. Wells, Desta Fekedulegn, Robert A. Perera, Torrance L. Nevels, Michael Wirth, Michael E. Andrew**
Document Number:	**309991**
Date Received:	**January 2025**
Award Number:	**2019-R2-CX-0021**

FINAL RESEARCH REPORT

Award Number: 2019-R2-CX-0021

Atypical Work Hours and Adaptation in Law Enforcement: Targets for Disease Prevention

December 6, 2024

Project Director: John M. Violanti, Research Professor

Co-Investigators: James B. Burch,[1] Jonathon Jacobs,[2] Jonathan L. Wells,[1] Desta Fekedulegn,[3] Robert A. Perera,[2] Torrance L. Nevels,[4] Michael Wirth,[5] Michael E. Andrew[6]

1 - Dept. of Epidemiology, School of Public Health, Virginia Commonwealth University, Richmond, VA.
2 - Dept. of Biostatistics, School of Public Health, Virginia Commonwealth University Richmond, VA.
3 - Bioanalytics Branch, Health Effects Laboratory Division, National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention, Morgantown, WV, USA.
4 - U.S. Military Interservice-Physician Assistant Program, MEDCoE, 3630 Stanley Rd, Bldg 2841. Joint Base San Antonio-Fort Sam Houston, San Antonio, TX, USA.
5 - College of Nursing, Arnold School of Public Health, University of South Carolina, Columbia, SC, USA.
6 - Retired, Bioanalytics Branch, Health Effects Laboratory Division, National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention, Morgantown, WV, USA.

Project Director Contact Information:

- E-mail: violanti@buffalo.edu
- Address:271 Farber Hall, University at Buffalo, SUNY, Buffalo. NY 14214
- Phone: 716-829-5481

Recipient Organization:

- The Research Foundation for SUNY on behalf of University at Buffalo, State University of New York, The UB Commons, 520 Lee Entrance, Suite 211, Amherst, NY 14228-2567

Project/Grant Period (Start Date, End Date) 01/01/2020-06/30/2024

Award Amount: $834,177.00

SUMMARY OF PROJECT

Major Goal and Objectives

The overall goal of this study was to characterize the extent to which work-related risk factors contribute to perturbations in physiological indicators of health and chronic disease. This research is important not only for furthering our understanding the role of atypical work hours in promoting adverse health outcomes, but also for developing and implementing strategies for protecting the health of workers in this high-risk occupation. Although some impacts of atypical work hours have been identified, the most effective or ineffective coping strategies that prospectively drive these processes remain to be fully elucidated. Few studies, if any, have addressed these critical data gaps by prospectively examining the impacts of atypical work hours. Evaluating trends in health indicators among police officers over time provides an opportunity to identify evidence-based strategies of adaptation to atypical work hours that are associated with normal biomarker trajectories among law enforcement officers.

The population studied in this investigation consisted of law enforcement officers enrolled in the Buffalo Cardiometabolic Police Stress (BCOPS) cohort. Atypical work hours were defined as: work outside of a standard daytime work shift, the number of shift changes that occur over an extended period, the effect of cumulative overtime hours, and/or secondary employment. This study also sought to examine the combined impacts of these work factors, and to test hypotheses that specifically target maladaptation to atypical work hours and whether intolerance to these work factors is associated with adverse trends in several chronic disease indicators, including: increases in biomarkers of inflammation and immunity; endocrine and metabolic dysregulation; decreases in heart rate variability (HRV), which is an indicator of autonomic nervous system dysregulation; and reductions in global DNA methylation, an indicator of genomic instability and risk factor for several types of cancer.

Research Questions

Aim 1.) Characterize impacts of atypical work hours on early biological indicators of chronic disease (immune, endocrine, metabolic, neurologic, epigenetic) by testing the hypothesis that shift work, overtime hours, and secondary jobs alter these measures over time.

Aim 2.) Conduct a survey among police officers to characterize strategies that police officers use to adapt to shift work, overtime, and secondary employment, and test the hypothesis that maladapted workers have specific traits, health behaviors, psychosocial circumstances, sleep/wake patterns, or other factors that differ from adapted workers.

Aim 3.) Characterize trajectories of adaptation/maladaptation to atypical work hours among police officers over time, examine changes in health indicators that are associated with different patterns of adaptation/maladaptation, and identify work-related adaptation strategies that are associated with beneficial or detrimental changes in the health indicators.

Aim 4.) Develop recommendations for implementing evidence-based strategies for adapting to atypical work hours that influence chronic disease indicators in police officers.

Because prior studies have been limited to cross-sectional analyses, this study adds to the current understanding of these issues by examining the role of adaptation/maladaptation to atypical work hours that occurred longitudinally over a median period of follow-up of ~12 years, thus capturing an appropriate temporal sequence of changes in biomarkers that may potentially be indicative of early disease onset. The identification of risk factors that either facilitate or detract from adaptation to atypical work hours that can aid in development and refinement of strategies to improve health and well-being among police officers, and to help prevent the onset of chronic diseases that have been associated with these facilitators of occupational stress.

Research Design

Methods

Aim 1

Analyses performed for Aim 1 utilized existing data from BCOPS cohort participants assembled over three waves of data collection (Figure 1). A total of 523 law enforcement officers originally recruited into the BCOPS study and data collection cycles occurred on three separate occasions beginning in 2006 and ending in 2021. At each study visit, participants completed validated questionnaires and provided biospecimens for analyses of chronic disease biomarkers. Participants were evaluated during the normal business hours of a clinic visit scheduled on an off day and not directly following an afternoon or night shift. Officers were asked to provide a detailed medical history, to self-report current medication usage, and to donate a ~10-hour fasting blood sample. The BCOPS protocol conforms to international ethical standards for human research.[1] The BCOPS study received Institutional Review Board approval from The State University of New York at Buffalo, the National Institute for Occupational Safety and Health, Virginia Commonwealth University, and other participating academic institutions. All participating law enforcement personnel provided written informed consent.

Questionnaires

Questionnaires were administered to ascertain information on sociodemographics (age, sex, race, years of service, rank, education), lifestyle behaviors (e.g., alcohol consumption, dietary factors, tobacco consumption, and physical activity), psychosocial circumstances, psychological traits and symptoms. Workplace physical activity was assessed using the seven-day Physical Activity Recall (PAR) questionnaire, an interviewer-administered questionnaire developed in the Stanford Five-City Project, and reported as the duration (hours/week and hours/weekend) and intensity (moderate, hard, and very hard) of physical activity during the previous seven days.[2]

Sleep quality was assessed using the Pittsburgh Sleep Quality Index (PSQI),[3] which consists of nineteen self or bed partner-rated questions that are used to characterize sleep: quality, onset latency, duration, efficiency, as well as sleep disturbance, sleep medication use, and daytime dysfunction. The global sleep score is a composite of the seven components, with higher scores indicating poorer sleep quality. A global score >5 was used as the cut-off for poor overall sleep.[3,4]

The Spielberger Police Stress Survey (SPPS)[5] is a validated 60-item instrument used to assess sources of occupational stress (scale: 0-100), with higher scores representing more stress. For each item, officers were asked to estimate the frequency with which they experienced the event in the previous month and year; however, for this analysis, scores across the 60-item were summed to obtain a total stress rating. In some cases, the three subscale scores were used instead of the total stress rating (1. administrative and organizational pressure, which measures satisfaction with departmental policies and procedures plus fairness of rewards, performance, and judicial system; 2. physical and psychological threats, which measures dangerous situations and experiences; and 3. lack of support, which includes political pressures and relationships with supervisors and coworkers).[5] Vital exhaustion (VE) was assessed using the 10-item Maastricht Questionnaire, which has three dimensions, i.e., feelings of: 1.) excessive fatigue and lack of energy; 2.) increasing irritability; and 3.) demoralization.[6] Perceived stress was measured using the 10-item Perceived Stress Scale (PSS), which is a validated and widely used instrument for stress perception.[7] Perceived stress scores are calculated by summing the Likert scale item responses, with higher scores representing greater perceived stress. Depressive symptoms were assessed using the Center for Epidemiologic Studies Depression Scale (CESD).[8] Participants with a score ≥16 are considered clinically depressed. Social support (SS) was measured using the Social Provision Scale, which consists of 22 items that assess six domains of social relationships.[9] A total score was derived by summing the score of all six subscales. Higher scores represent more social support, and participants with a total score <75% percentile were considered to have low social support.

Personality traits were measured using the Neuroticism-Extraversion-Openness Five-Factor Inventory (NEO-FII),[10,11] which is a shortened version of the NEO Personality Inventory that includes the following traits: neuroticism, openness to experience, extraversion, conscientiousness, and agreeableness. Each item is rated on a five-point Likert scale, ranging from strongly disagree to strongly agree. Higher scores indicate a stronger presence of a given trait.

Hardiness was assessed using the 15-item Dispositional Resilience Scale (DRS) instrument developed by Bartone et al,[12] which is comprised of three dimensions, including control (belief one is capable of managing stressful events), commitment (ability to find meaning in stressful events), and challenge (ability to interpret stressful events as opportunities). Each item is rated on a four-point Likert scale that ranges from not at all true to completely true. A summary score is obtained by appropriately coding and summing all 15 items, where a larger score is interpreted as having more hardiness.

The Family Environment Scale (FES) is a 90-item measure that assesses three dimensions of familial interactions and social environment (relationships, personal growth, system maintenance).[13] It is comprised of 10 subscales (cohesion, expressiveness and conflict, independence, achievement orientation, intellectual-cultural orientation, active-recreational orientation, moral religious emphasis, and organization and control). Total scores (range: 0-9) are obtained by adding each value in the respective subscale; higher scores indicate a higher degree of perceived family interaction for the specified dimension.

Work Factors

Work histories were summarized for each participant using available administrative records. Electronic work history data from 1994 to 2010 were available for 430 participants. The time of day that participants started their regular work shift was used to classify each record into one of the following three categories: day shift (start time between 4 am and 11 am); evening shift (start time between 12 pm and 7 pm); night shift (start time between 8 pm and 3 am). Total hours worked as well as hours worked at the day, evening and night shift were summed for each participant over all available work shift records. Considering the length of time a participant was working (from first date of work history data to date of exam at Exam 1), the computed hours were standardized to a weekly basis (hours worked per week) and percent of total hours worked on each type of shift was calculated. The 'dominant shift' was assigned to each participant based on the highest percentage. Work factors that were examined in the statistical analyses included: dominant shift (days, evenings, nights, or evenings and nights combined); the total number of career shift changes (tertiles), the presence of a second job (none, <1 work shift per week, ≥1 work shift per week), and cumulative overtime hours (tertiles).

In addition to these work factors, an 'occupational stress' variable was created to examine the combined effects of the work factors of interest using a single classification scheme. An occupational stress score was calculated based on the participant's classification within each work factor category as follows: dominant shift (1=night/evening, 0=day), second job (1=person has second job, 0=no second job), shift change tertiles (2=high, 1=moderate, 0=low), and cumulative overtime hour tertiles (2=high, 1=moderate, 0=low), then summing their assignment to each work factor (score range: 0 to 6). Those with an occupational stress score of 5-6 were assigned to the high occupational stress category, those with a score of 2-4 were assigned to the intermediate category, and those with a score of 0-1 were assigned the low category.

Biomarkers

Continuous biomarker variables of interest included immune, endocrine, metabolic, neurological and epigenetic markers that have been previously identified as potential indicators of early disease onset. Immune and inflammation mediators included in this analysis were: C-reactive protein (CRP), interleukin-6 (IL-6), tumor necrosis factor alpha (TNF-alpha), white blood cell count (WBC), intercellular adhesion molecule one (ICAM-1), homocysteine, and fibrinogen. A dichotomous biomarker was established for CRP based on prior studies of adverse cardiovascular and related health outcomes (≥3 mg/L).[14] Endocrine biomarkers included: insulin, leptin, adiponectin, thyroid stimulating hormone (TSH), and triiodothyronine (T3).

Measures of metabolic function included the liver function enzymes, alanine aminotransferase (ALT) and aspartate aminotransferase (AST), as well as triglycerides, total cholesterol, high and low density lipoprotein (HDL and LDL, respectively), the cholesterol:HDL ratio, blood glucose, estimated average blood glucose (EAG), hemoglobin A1C (HBA1c), and the glomerular filtration rate (GFR). Indicators of metabolic syndrome (MetS) included whether the individual met criteria for a MetS diagnosis (yes/no) based on consensus criteria,[15] and the sum of the individual MetS criterion values that were exceeded. Participants were classified as having metabolic syndrome if they met at least three of the following criteria: waist circumference >102 cm for men and >88 cm for women; triglycerides ≥150 mg/dl, HDL cholesterol <40 mg/dl for men and <50 mg/dl for women; blood pressure ≥130/85 mmHg; or serum glucose ≥110 mg/dl. In addition, a MetS severity score (MSSS) was calculated as a continuous version of traditionally defined MetS classification allowing for sex and racial/ethnic differences in waist circumference, triglycerides, systolic blood pressure, HDL-cholesterol, and fasting glucose.[16] The MSSS can be interpreted as a z-score with a normal distribution and a value of 0 indicating "average" MetS severity, and higher or lower scores reflecting greater or less MetS severity, respectively.[16] For example, a MSSS value of 1 indicates MetS severity that is one standard deviation worse than the population average. The methods describing the quantification of the above measures have been previously described.[17] Variables designating the number of MetS criteria that were met by each individual and MetS severity were included in the Aim 1 analyses.

HRV measures used in this analysis included time-domain (standard deviation of NN heart beat intervals or SDNN, and the root mean square of successive RR intervals or RMSSD), as well as high-frequency (HF) and low-frequency (LF) frequency-domain HRV measures derived using two different spectral analysis methods (Burg and Welch) as follows: HF-Burg, HF-Welch, LF-Burg, LF-Welch. Methods used for HRV measurement in the BCOPS cohort have been summarized previously.[18]

Global DNA methylation was quantified using average percent methylation values of long interspersed nuclear elements (LINE-1). LINE-1 DNA methylation was measured using an established pyrosequencing method by a commercial laboratory (EpigenDx, Hopkinton, MA, USA). Initially, DNA was extracted from previously acquired peripheral white blood cells collected from each participant at their clinic visit. Bisulfite polymerase chain reaction (PCR) amplification was performed on a 36-base pair sequence that is conserved within each LINE-1 element across the genome, and methylation was measured at four CpG sites contained within that repetitive sequence. The percent of methylated reads was calculated at each CpG site by dividing the number of methylated reads over the total number of reads. LINE-1 methylation was summarized by averaging the percent methylation across the four CpGs within each individual's sample.

Statistical Analyses

Statistical analyses were performed using the SAS 9.4 statistical software package with a nominal type-I error rate of $\alpha=0.05$. Descriptive statistics were generated by summarizing the sociodemographic characteristics of those participating at each study visit. The following variables exhibited sufficient skewness to warrant log-transformation: CRP, IL-6, insulin, leptin, homocysteine, ALT, adiponectin, GFR, HF-Burg, and LF-Burg. GFR was combined across all race groups. Mixed effects regression models were fit to test the Aim 1 hypotheses examining the relationship between each work factor (independent variable) and each biomarker of interest (dependent variable). Study visit was included in each model to account for the repeated measures within each person assuming an autoregressive correlation structure of order 1 (AR[1]). Separate analyses were performed for each comparison, and adjustment for multiple comparisons was not conducted since each comparison was considered an *a priori* hypothesis. All models were adjusted for age, sex, race, education level, marital status, police rank, and chronotype (morning/neutral/evening). Morningness was defined as bedtimes between 1800 and 2215 hours. A neutral chronotype was defined as a bedtime between 2215 and 0030 hours. An evening chronotype was defined as a bedtime between 0030 and 0500 hours. Participants with bedtimes outside of these times were recorded as missing, since morning/eveningness becomes ambiguous outside of standard bedtime hours. For each model, statistical tests were performed for each work factor of interest based on type III sums of squares. Post-hoc contrasts of adjusted (least squares or LS) means at each time point were estimated using those with no or low exposure as the referent (i.e., day shift, no second job, lowest tertile of shift changes or cumulative overtime hours). Results were displayed graphically as LS means by work factor group and study visit, and were grouped according to major outcome categories of interest (immune/inflammatory, endocrine, metabolic, neurologic [HRV], epigenetic [LINE-1 DNA methylation]).

Outcome Aim 1

The composition of the cohort including the number of participants in each data collection cycle is presented in Figure 1. There were 464 participants in the first data collection cycle (Exam 1), 300 participants at Exam 2, and 240 in Exam 3. The median follow-up time was 7 years between Exams 1 and 2, and 5 years between Exams 2 and 3. There were 176 BCOPS cohort members who participated in all three data collection cycles. The overall median follow-up time was 12 years, and there were 1,569 data records available for the analysis.

Sociodemographic characteristics of BCOPS cohort members included in Aim 1 analyses are presented in Table 1.1 for the overall study population and stratified by study visit. Participants were predominantly male (74%), European Americans (52%) with a college education (58%). The average age (±SD) was 45±9 years, and the average work duration was 18±9 years. The most common rank was police officer (38%) with equally distributed numbers among the higher ranks (Sergeant/Lieutenant/Captain: 12%; Detective/Executive/Other: 12%). BCOPS personnel who worked less than one shift at a second job each week put in an average of 5±1 hours per week, whereas those with ≥1 shift worked an average of 15±7 hours per week at a second job. Those in the upper tertile of cumulative overtime worked an average (±SD) of 5±2, 5±2, and 6±2 extra hours per week at Exams 1, 2 and 3, respectively, whereas those in the intermediate tertile had 2±0.4, 2±0.4, and 3±0.5 extra hours per week, and those in the lower tertile worked an average of 1±1, 0.3±1, and 1.4±0.5 overtime hours per week. Approximately 28% of the study population worked days as their dominant shift, whereas 21% worked evenings and 13% nights (Table 1.1). The average (±SD) number of shift changes among those in the upper tertile was 79±55, 136±80, and 168±108 at Exams 1, 2 and 3, respectively, while those in the intermediate tertile had 25±6, 45±13, and 52±15, and those in the low tertile had 9±4, 11±7, and 14±8 shift changes at those study visits, on average. Work related characteristics of personnel in each category of the Occupational Stress score are presented in Table A.1 (Appendix, see below). Among those in the high Occupational Stress category, 90% worked evenings or nights as their dominant shift, 88% were in the upper tertile of shift changes, 52%

worked one or more shift at a second job each week, and 80% were in the upper tertile of cumulative overtime hours (Table A.1).

Tables 1.2a and 1.2b summarize results comparing LS mean biomarker levels at each study visit relative to categories of atypical work hours that were examined in this analysis. Effect estimates for differences in the adjusted (LS) mean biomarker levels among those in the highest exposure groups (i.e., working evenings/nights, frequent shift changes, or those with second jobs, more cumulative overtime, or high occupational stress scores) are presented for variables that achieved statistical significance relative to their reference group (Tables 1.2a and 1.2b). Graphs displaying the relationship between LS means of all biomarkers that were evaluated are available upon request.

Among those in the upper tertile of shiftwork changes, several biomarkers were altered in a manner that supported the study hypotheses, relative to those in the lowest tertile, including increases in the liver function enzymes, ALT ($p<0.05$, Exams 2 and 3) and AST ($p<0.05$, Exam 2), as well as increases in total cholesterol at Exams 2 ($p<0.05$) and 3 ($p<0.001$), and an increase in LDL cholesterol at Exam 3 ($p<0.01$, Table 1.2a). Similarly, statistically significant reductions in several HRV measures were observed among those in the intermediate or upper tertile of work shift changes (or both) relative to those in the low tertile, including lower adjusted means of SDNN, RMSSD, LF-HRV and HF-HRV (Table 1.2a).

For those working evenings or nights as their dominant shift, there were several changes in biomarkers that supported the study hypotheses. The HRV biomarkers, RMSSD and LF-HRV (Welch), were lower among those working evenings ($p<0.05$), or evenings/nights combined ($p<0.05$) at Exam 3 relative to those working days (Table 1.2a). Among those working nights, WBC counts were elevated at Exam 1 ($p<0.05$), but not at other study visits (Table 1.2a). Unanticipated changes in GFR, glucose, homocysteine, HbA1c, and the number of MetS criteria that were met were noted among those working evenings or nights, inconsistent with hypothesized changes. This only occurred for one biomarker (ALT) for analyses of shift changes as the exposure of interest (Table 1.2a).

Relative to those without a second job, working a second job was associated with elevated LS means for total cholesterol ($p<0.05$), and cholesterol:HDL ratios at Exam 1 ($p<0.05$), and with reduced adiponectin ($p<0.05$) and TSH ($p<0.001$) at Exam 3 (Table 1.2b). Those in the upper tertile of cumulative overtime hours had elevated levels of LDL cholesterol ($p<0.05$) as well as lower mean LF-HRV ($p<0.05$) and HF-HRV ($p<0.05$) at Exam 3 relative to those in the lowest tertile (Table 1.2b). Occupational stress was associated with higher levels of total cholesterol (Exams 1 and 3, $p<0.01$ and $p<0.05$, respectively), and with increased LDL cholesterol at Exam 1 (intermediate: $p<0.01$, or high occupational stress: $p<0.05$), and at Exam 3 (high occupational stress: $p<0.05$), relative to the low occupational stress group (Table 1.2b). Occupational stress was also associated with higher cholesterol:HDL ratios and elevated CRP at Exam 1 (intermediate group, both $p<0.05$, Table 1.2a). Lower values of all HRV metrics were observed at Exam 3 for both the intermediate and high occupational stress groups relative to those with negligible occupational stress (Table 1.2b). Unexpected increases in GFR were also noted among those in the intermediate and high occupational stress groups at Exam 1 (Table 1.2a).

Figure 1. The Buffalo Cardio-Metabolic Occupational Police Stress (BCOPS) study design and sample size.

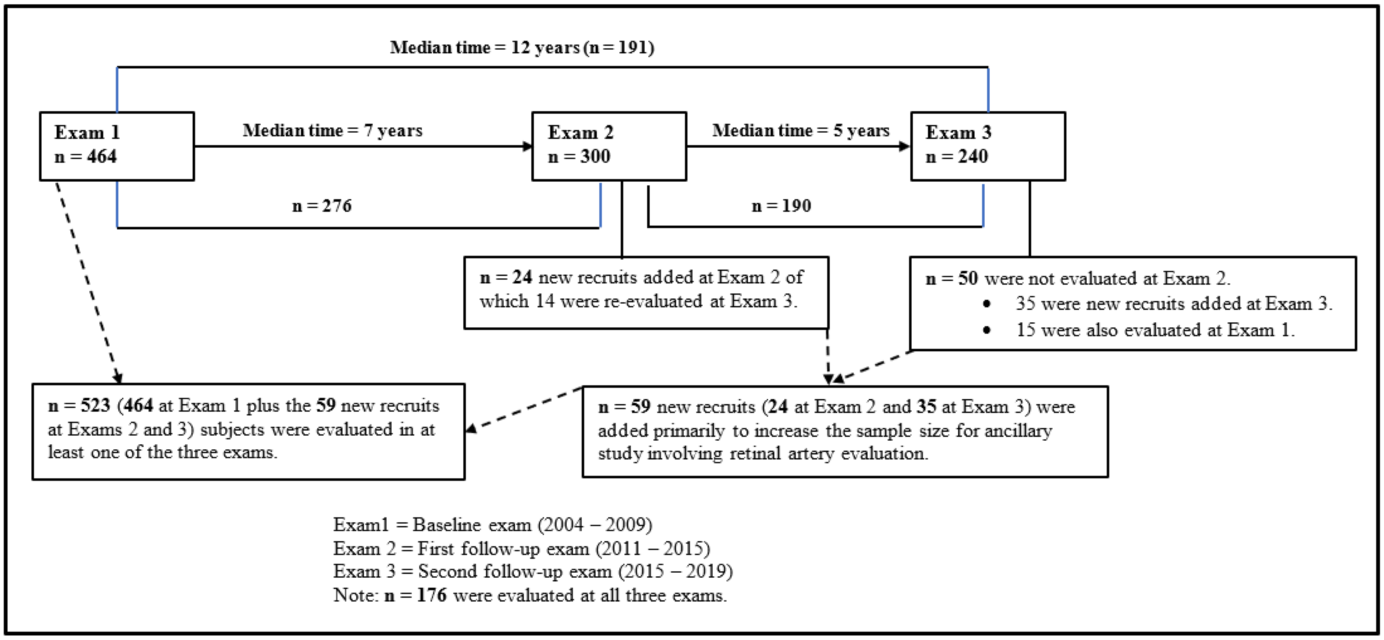

Table 1.1: Population Characteristics of BCOPS Cohort Study, 2008 - 2021

Characteristic	Exam 1	Exam 2	Exam 3	Overall (N=1,569 obs)
Age				
Mean (SD)	42 (9)	47 (9)	49 (10)	45 (9)
Median [Min, Max]	41 [21, 74]	47 [23, 73]	50 [21, 78]	45 [21, 78]
Missing	59 (11%)	223 (43%)	283 (54%)	565 (36%)
Race / Ethnicity n (%)				
European American	378 (72%)	237 (45%)	195 (37%)	810 (52%)
African American	91 (17%)	58 (11%)	42 (8%)	191 (12%)
Hispanic	9 (2%)	5 (1%)	3 (1%)	17 (1%)
Missing	45 (9%)	223 (43%)	283 (54%)	551 (35%)
Sex n (%)				
Female	137 (26%)	137 (26%)	137 (26%)	411 (26%)
Male	386 (74%)	386 (74%)	386 (74%)	1158 (74%)
Marital Status n (%)				
Single	55 (11%)	38 (7%)	32 (6%)	125 (8%)
Married	338 (65%)	203 (39%)	168 (32%)	709 (45%)
Divorced	61 (12%)	57 (11%)	39 (8%)	157 (10%)
Missing	69 (13%)	225 (43%)	284 (54%)	578 (37%)
Education Level n (%)				
High School (≤12 yrs)	50 (10%)	24 (5%)	11 (2%)	85 (5%)
College (13-15 yrs)	249 (48%)	151 (29%)	122 (23%)	522 (33%)
Graduate (≥16 yrs)	155 (30%)	125 (24%)	107 (21%)	387 (25%)
Missing	69 (13%)	223 (43%)	283 (54%)	575 (37%)
Police Rank n (%)				
Police officer	312 (60%)	171 (33%)	119 (23%)	602 (38%)
Sgt/Lt/Capt	72 (14%)	58 (11%)	60 (12%)	190 (12%)
Detect/Exec/Other	66 (13%)	67 (13%)	58 (11%)	191 (12%)
Missing	73 (14%)	227 (43%)	286 (55%)	586 (37%)
Years Served				
Mean (SD)	15 (8)	20 (9)	20 (9)	18 (9)
Median [Min, Max]	16 [0, 41]	18.5 [1, 45]	20 [0, 44]	18 [0, 45]
Missing	69 (13%)	223 (43%)	283 (54%)	575 (37%)
Military Service n (%)				
No	334 (64%)	230 (44%)	195 (37%)	759 (48%)
Yes	120 (23%)	69 (13%)	45 (9%)	234 (15%)
Missing	69 (13%)	224 (43%)	283 (54%)	576 (37%)
Dominant Shift n (%)				
Days	188 (36%)	139 (27%)	112 (21%)	439 (28%)
Evenings	142 (27%)	99 (19%)	81 (16%)	322 (21%)
Nights	100 (19%)	60 (12%)	46 (9%)	206 (13%)
Evenings & Nights Combined	242 (46%)	159 (31%)	127 (24%)	528 (34%)
Missing	93 (18%)	225 (43%)	284 (54%)	602 (38%)
Second Jobs n (%)				
None	297 (57%)	204 (39%)	149 (29%)	650 (41%)
<8 hrs/week	38 (7 %)	20 (4%)	24 (5%)	82 (5%)
≥8 hrs/week	114 (22%)	63 (12%)	67 (13%)	244 (16%)
Missing	74 (14%)	236 (45%)	283 (54%)	593 (38%)
Cumulative Overtime Tertiles n (%)				
Low	214 (41%)	303 (58%)	343 (66%)	860 (55%)
Medium	142 (27%)	98 (19%)	79 (15%)	319 (20%)
High	147 (28%)	102 (20%)	81 (16%)	330 (21%)
Missing	20 (4%)	20 (4%)	20 (4%)	60 (4%)

Table 1.1: Population Characteristics of BCOPS Cohort Study, 2008 - 2021

Characteristic	Exam 1	Exam 2	Exam 3	Overall (N=1,569 obs)
Shift Change Tertiles n (%)				
Low	232 (44%)	307 (59%)	344 (66%)	883 (56%)
Medium	125 (24%)	95 (18%)	78 (15%)	298 (19%)
High	146 (28%)	101 (19%)	81 (16%)	328 (21%)
Missing	20 (4%)	20 (4%)	20 (4%)	60 (4%)
Occupational Stress Score[a] n (%)				
Low	177 (34%)	300 (57%)	327 (63%)	804 (51%)
Medium	197 (38%)	125 (24%)	109 (21%)	431 (27%)
High	149 (28%)	98 (19%)	87 (17%)	334 (21%)
Number of Sick Days				
Mean (SD)	0.98 (0.93)	0.76 (0.87)	0.80 (0.80)	0.87 (0.89)
Median [Min, Max]	1 [0, 4]	1 [0, 4]	1 [0, 3]	1 [0, 4]
Missing	76 (15%)	233 (45%)	283 (54%)	592 (38%)

Column percentages may not equal 100% due to rounding or missing data. obs: observations. a - Participants were assigned an occupational stress score based on their combined classification within groups of: dominant shift, shift changes, second jobs, and cumulative overtime hours (range: 0-6); high occupational stress score: 5-6; medium: 2-4; low: 0-1, see methods). There were 523 unique participants in the study, not all of them were available at each visit. The number missing from each visit is recorded for each variable.

Table 1.2a: Effect Estimates for Differences between Adjusted Means for Chronic Disease Indicators vs. Referent Group, by Study Visit: Shiftwork Variables (N=1,569 obs, BCOPS Study, 2024)

Outcome	Dominant Work Shift					
	Exam 1		Exam 2		Exam 3	
	E v. D	N v. D	E v. D	N v. D	E v. D	N v. D
Cardiometabolic Measures						
Est. Ave. Glucose	-4.02*	-3.86	0.93	-0.56	-0.72	-1.51
log(Homocysteine)	-0.04	-0.02	-0.03	-0.05	-0.02	-0.13**
HbA1c	-0.14*	-0.13	0.03	-0.02	-0.03	-0.05
No. of MetS Criteria	-0.02	-0.10	-0.09	-0.04	-0.51**	-0.29
Heart Rate Variability						
RMSSD	0.39	-1.21	1.62	2.66	**-10.32***	-6.17
Immune & Inflammation Measures						
WBC	0.25	**0.46***	-0.13	0.36	0.09	0.23

Outcome	Evenings or Nights versus Day Shift		
	Exam 1	Exam 2	Exam 3
	E&N v. D	E&N v. D	E&N v. D
Cardiometabolic Measures			
Est. Ave. Glucose	-3.37*	0.69	-0.85
HbA1c	-0.12*	0.02	-0.03
No. of MetS Criteria	-0.04	-0.07	-0.43**
Heart Rate Variability			
RMSSD	1.72	1.81	**-9.99***

Outcome	Shift Change Tertiles[a]					
	Exam 1		Exam 2		Exam 3	
	Med v. Low[b]	High v. Low	Med v. Low	High v. Low	Med v. Low	High v. Low
Cardiometabolic Measures						
log(ALT)	---	---	0.02	**0.10***	**0.14***	0.06
AST	---	---	0.54	**2.59***	2.50	0.74
Total Cholesterol	3.19	1.67	2.76	**9.05***	10.41	**19.08*****
log(GFR)	0.038*	0.006	-0.002	-0.007	0.002	0.004
LDL Cholesterol	6.70	1.91	3.09	5.77	9.50	**14.66****
Heart Rate Variability (HRV)						
SDNN	-1.53	0.61	-1.16	1.35	**-10.32***	-7.67
RMSSD	-0.16	1.82	-2.28	1.55	**-14.38****	**-12.01***
log(LF-Burg)	0.10	0.13	0.08	0.13	**-0.43***	-0.19
HF-Welch	-59.28	18.66	-82.66	-42.00	**-425.94****	-283.34
LF-Welch	-33.03	14.45	-58.77	-77.38	**-407.24*****	**-317.75****

*: $p < 0.05$, **: $p < 0.01$, ***: $p < 0.001$. All models adjusted for: age, sex, race, education, marital status, police rank, and chronotype (bold values support the study hypotheses). D: Days (referent). E: Evenings. N: Nights. ALT: alanine aminotransferase. a - by exam tertile; E1: high >37, med 16-37, low 0-15; E2: high >69, med 25-69, low 0-24; E3: high >80, med 30-80, low 0-29. b - low (referent). AST: aspartate aminotransferase. HbA1c: hemoglobin A1C. GFR: glomerular filtration rate. LDL: low-density lipoprotein. HDL: high-density lipoprotein. MetS: metabolic syndrome. TSH: thyroid stimulating hormone. SDNN: standard deviation of normal-to-normal heart beat intervals. RMSSD: root mean square of successive RR intervals. HF: high frequency HRV. LF: low frequency HRV. WBC: white blood cell count.

Table 1.2b: Effect Estimates for Differences between Adjusted Means for Chronic Disease Indicators vs. Referent Group, by Study Visit: Nonshiftwork Variables (N=1,569 obs, BCOPS Study, 2024)

Outcome	Second Jobs[a]					
	Exam 1		Exam 2		Exam 3	
	Med v. Low	High v. Low	Med v. Low	High v. Low	Med v. Low	High v. Low
Cardiometabolic Measures						
log(Adiponectin)	0.17	0.07	-0.10	0.10	**-0.34***	0.14
Total Cholesterol	5.15	**8.58***	2.13	1.33	5.83	4.89
Cholesterol:HDL	0.15	**0.35***	-0.31	0.12	0.17	0.13
Endocrine Measures						
TSH	-0.02	-0.04	-0.03	-0.06	**-0.93*****	-0.19

Outcome	Cumulative Overtime Hour Tertiles[b]					
	Exam 1		Exam 2		Exam 3	
	Med v. Low	High v. Low	Med v. Low	High v. Low	Med v. Low	High v. Low
Cardiometabolic Measures						
LDL Cholesterol	3.80	5.73	4.85	5.67	7.02	**11.29***
MetS Severity	-0.19*	-0.12	0.04	0.06	-0.06	0.04
Heart Rate Variability (HRV)						
HF-Welch	-72.36	-15.47	-116.48	-116.47	-175.75	**-284.24***
LF-Welch	-58.68	-44.65	-43.67	-3.48	-187.54	**-223.24***

Outcome	Occupational Stress Score[c]					
	Exam 1		Exam 2		Exam 3	
	Med v. Low	High v. Low	Med v. Low	High v. Low	Med v. Low	High v. Low
Cardiometabolic Measures						
AST	---	---	-0.54	1.21	**3.88****	2.94
Total Cholesterol	**13.26****	6.91	-1.78	4.20	3.60	**15.67***
Cholesterol:HDL	**0.40***	0.18	-0.07	0.20	0.05	0.30
log(GFR)	0.07***	0.05*	-0.001	-0.003	-0.003	-0.003
LDL Cholesterol	**12.91****	**8.50***	-3.05	2.40	1.42	**13.35***
Heart Rate Variability (HRV)						
SDNN	-3.57	-1.82	-4.19	-2.05	**-9.40***	**-12.23****
RMSSD	-6.08	-1.62	-3.02	-2.41	**-11.73***	**-18.22****
HF-Welch	-151.94	-50.50	-98.46	-142.54	**-492.12****	**-488.31****
LF-Welch	-53.30	-24.17	-66.05	-70.46	**-491.83*****	**-460.92*****
Inflammatory Cytokines						
log(CRP)	**0.27***	0.16	0.01	0.08	0.25	-0.03

*: $p < 0.05$, **: $p < 0.01$, ***: $p < 0.001$. All models adjusted for: age, sex, race, education, marital status, police rank, and chronotype (bold values support the study hypotheses). a - Low: No 2[nd] Job, Med: <1 shift/week, High: ≥1 shift/week. b - tertiles (hrs/week) by exam; E1: high >2.76, med >1.3-2.8, low 0-1.3; E2: high >3.2, med >1.5-3.2, low 0-1.5; E3: high >3.9, med >2.1-3.9, low 0-2.1. c - See Table 1.1 legend for definition. Low (referent). AST: aspartate aminotransferase. CRP: C-reactive protein. HbA1c: hemoglobin A1C. MetS: metabolic syndrome. LDL: low-density lipoprotein. HDL: high-density lipoprotein. TSH: thyroid stimulating hormone. RMSSD: root mean square of successive RR intervals. HF: high frequency HRV. LF: low frequency HRV. SDNN: standard deviation of normal-to-normal heart beat intervals.

APPENDIX - Aim 1

Table A.1. Work Characteristics of Police Personnel by Occupational Stress Category, BCOPS Study, 2024 (N=948 obs)[1]

Work Factor	Low Occupational Stress (n)	%	Moderate Occupational Stress (n)	%	High Occupational Stress (n)	%
Dominant Shift (n)	183	19%	611	64%	154	16%
Days	143	78%	266	44%	15	10%
Evenings	11	6%	198	32%	111	72%
Nights	29	16%	147	24%	28	18%
Evenings & Nights	40	22%	345	56%	139	90%
Second Jobs (n)	182	19%	606	64%	153	16%
None	167	92%	408	67%	51	33%
<1 Shift per Week	3	2%	48	8%	22	14%
≥1 Shift per Week	12	7%	150	25%	80	52%
Shift Changes (n)	183	19%	611	64%	154	16%
Low Tertile	159	87%	172	28%	0	0%
Middle Tertile	24	13%	251	41%	19	12%
Upper Tertile	0	0%	188	31%	135	88%
Overtime Hours (n)	183	19%	611	64%	154	16%
Low Tertile	147	80%	168	27%	0	0%
Medium Tertile	36	20%	248	41%	31	20%
Upper Tertile	0	0%	195	32%	123	80%

1 - number of observations for each work factor over all three study visits.

Specific Aim 2

AIM 2 - *Conduct a survey among police officers to characterize strategies that police officers use to adapt to shift work, overtime, and secondary employment, and test the hypothesis that maladapted workers have specific traits, health behaviors, psychosocial circumstances, sleep/wake patterns, or other factors that differ from adapted workers.*

The objective of Aim 2 was to conduct a new detailed survey among police officers to better characterize strategies that police officers use to adapt to shift work, overtime, and secondary employment. Participants were asked to rank their most important strategies (What strategies are most important to you for adapting to your work schedule?), and descriptive statistics were then used to summarize the most prevalent self-reported shiftwork adaptation strategies. The data were stratified among Aim 2 participants grouped according to several work-related factors of interest (dominant shift, shiftwork adaptation/maladaptation, and an occupational stress score that was defined based on a participant's combined membership in each of the other work factor groups). Analyses were performed to identify sociodemographic, behavioral, lifestyle, and occupational factors, psychosocial traits, personal/familial circumstances, or sleep/wake patterns that differed between adapted and maladapted workers. Subsequent analyses examined whether preclinical biomarkers (cardiometabolic, endocrine, inflammatory/immune, neurologic, epigenetic) differed between the adapted and maladapted groups. Participants were also asked to complete a food log for two non-consecutive workdays and one non-work day.[19]

Aim 2 Methods

Police officers (N=159) currently enrolled in the BCOPS study were recruited to complete a survey conducted between 2021 and 2023 that focused on factors associated with shiftwork adaptation (see Appendix for Aim 2 questionnaire). The survey was developed based on a literature review of existing studies that administered questionnaires concerning the impacts of shift work and shiftwork adaptation strategies.[17,20-32] Questions included direct items about self-reported shiftwork adaptation (i.e., Do you consider your work performance optimal on your current work schedule?, Are you content with your current work schedule?, and 'On a scale from 0-10, how adapted are you to your current work schedule?),[24] as well as qualitative items about strategies that officers use to adjust to their work schedule. Responses to these questions (e.g., strongly disagree, disagree, neutral, agree, strongly agree) were coded so that higher scores represent greater adaptation or satisfaction. Symptoms of depression, anxiety, police stress, persistent stress, social support, and sleep quality were acquired from each participant's most recent data collection cycle within the BCOPS cohort (2019-2021). Work related variables of interest were categorized as follows: dominant work shift (day, evening, night, plus those working either evenings or nights); the total number of career shift changes (tertiles), the presence of a second job (none, <1 work shift, ≥1 work shift per week), and cumulative work hours (tertiles). An occupational stress variable was also created that combined each of these work factors into a single classification. Latent class analysis (LCA) was used to classify Aim 2 survey respondents into groups with symptoms that are indicative of shiftwork adaptation or maladaptation. Groups defined using the LCA were then compared to the direct shiftwork adaptation questions also included in the Aim 2 survey. These analyses were performed in part to further evaluate the validity of a previous analysis of shiftwork adaptation among BCOPS police officers[17] that did not have direct shiftwork adaptation questions available for comparison between the LCA-derived groups.

Note that the Aim 2 analyses included n=54 individuals from the prior study.[17] However, these analyses differed in two important ways. First, the current analysis was performed at a later time point (up to ~12 years later than analyses performed for the previous study). Second, the current analysis included individuals assigned to day shifts in addition to those working evenings or nights using the same symptom questionnaires, whereas the previous analysis only included evening and night workers. This was done because workers assigned to permanent day shifts still occasionally encounter situations in which they are required to fill in for co-workers on an evening or night shift, and including these individuals allowed for a broader range of responses to the shiftwork adaptation/maladaptation questions to be integrated into the analysis. Subsequent Aim 2 analyses examined whether sociodemographic, behavioral, lifestyle, and occupational factors, psychosocial traits, personal/familial circumstances, or sleep quality differed between adapted and maladapted workers. Finally, analyses were performed to examine differences in immune, endocrine, metabolic, neurologic, and epigenetic

(LINE-1 DNA methylation) biomarkers between the adapted and maladapted groups. Biomarkers included in these analyses encompassed a broad range of preclinical disease indicators that matched those used in the Aim 1 analyses. Aim 2 analyses were performed in the R 4.3.2 statistical software package with a nominal type I error rate of $\alpha=0.05$. More detailed methods used for each step of the Aim 2 analysis are provided below. (See Aim 1 Methods for a more detailed description of methods used for collection of psychometric measures, biomarkers, work related factors, and other data).

To characterize prevalent shiftwork adaptation strategies, participants were asked the following question: 'What strategies are most important to you for adapting to your work schedule?' and were asked to rank their top five most important strategies (getting the right amount of sleep, getting sleep timing right, making sure the bedroom/home environment promotes good sleep, using sedatives/sleep aids, napping, alcohol consumption, tobacco or nicotine use, use of caffeinated beverages or other stimulants, diet, exercise, family/housemate support, and workplace manager/supervisor support. Responses to these items were coded so that higher scores represent the most important strategies. Weighted sums were computed so that responses with the highest rankings had higher scores, and the rankings for each item were summarized graphically. Responses to questions addressing work schedule impacts were summarized in a similar manner (Are you satisfied with the amount of time your work shift leaves you for: hobbies/sports, spouse/partner, friends/family, cultural events, social organizations, adult education, health care, domestic tasks, religious activities, hobbies, shopping, weekend/family outings, personal time?), with higher rankings representing greater satisfaction. These analyses were performed among Aim 2 participants stratified according to work related factors of interest (dominant shift, and LCA-defined shiftwork adaptation/maladaptation status).

Continuous biomarker variables of interest included immune, endocrine, metabolic, neurological and epigenetic indicators of early disease onset. Immune or inflammation mediators included: C-reactive protein (CRP), interleukin-6 (IL-6), tumor necrosis factor alpha (TNF-alpha), white blood cell count (WBC), intercellular adhesion molecule one (ICAM-1), homocysteine, and fibrinogen. Endocrine biomarkers included: insulin, leptin, adiponectin, thyroid stimulating hormone (TSH), and triiodothyronine (T3). Measures of metabolic function included the liver function enzymes, alanine aminotransferase (ALT) and aspartate aminotransferase (AST), as well as triglycerides, total cholesterol, high- and low-density lipoprotein (HDL and LDL, respectively), the cholesterol:HDL ratio, blood glucose, estimated average blood glucose (EAG), hemoglobin A1C (HBA1c), and glomerular filtration rate (GFR). Indicators of metabolic syndrome (MetS) included the number of criteria that a given participant met, and their MetS severity score (MSSS). Heart rate variability (HRV) measures included: time domain (standard deviation of NN heart beat intervals or SDNN, and the root mean square of successive RR intervals or RMSSD), as well as high frequency (HF) and low frequency (LF) HRV measures derived using two different spectral analysis methods (Burg and Welch) as follows: HF-Burg, HF-Welch, LF-Burg, LF-Welch. Finally, global DNA methylation was estimated using average percent methylation values of long interspersed nuclear elements (LINE-1). The following variables exhibited sufficient skewness to warrant log-transformation: CRP, IL-6, insulin, leptin, homocysteine, ALT, adiponectin, GFR, HF-Burg, and LF-Burg.

Scores for symptoms of depression, anxiety, police stress, persistent stress, vital exhaustion, social support, and sleep/wake patterns among the Aim 2 survey respondents were used to conduct LCAs to identify groups of individuals with low and high symptom scores indicative of shiftwork adaptation or maladaptation, respectively. Two LCA models were generated as described previously,[17] a police-specific model that used all the symptoms described above, and a general symptom model that excluded data on police stress and sleep quality. Symptom scores were dichotomized so that higher values represented worse symptoms. For example, a 1 for social support indicated the lowest quartile of social support, and 0 represented more social support, while a 1 for perceived stress indicated the highest quartile of stress, and 0 represented lower quartiles of the stress score. A swap-stepwise variable selection procedure was applied using R software (LCAvarsel package) to identify the best-fitting models. For each analysis, 1 to 4 latent classes were examined iteratively to identify the optimal number of symptom classes that minimized the Bayesian Information Criterion (BIC). The probability of group membership for each symptom was then calculated and displayed graphically.

Univariate logistic regression models were used to identify participant characteristics that differed between the LCA-defined adaptation/maladaptation groups using symptoms acquired from the participant's most recent BCOPS study visit. Responses to direct shiftwork adaptation items from the Aim 2 survey were averaged and differences between the shiftwork adaptation/maladaptation groups were compared statistically via a t-test. The distribution of responses to the direct adaptation questions was also plotted graphically with stratification by adaptation/maladaptation group. Other variables of interest for comparison between the adapted/maladapted LCA groups included demographic, occupational, and behavioral/lifestyle factors (e.g., years served, physical activity level, marital status, tobacco use, education level, police rank, race, body mass index (BMI), dominant work shift, shift changes, overtime hours, second job, total drinks per week, servings of fat, servings of fruits and vegetables). In addition, several psychological traits and states were evaluated including: hardiness, family environment, and sleep/wake patterns. For continuous variables, differences between means were compared statistically via a t-test, and for categorical variables, proportions in the adaptation/maladaptation groups were compared via a chi-squared test (Fisher's exact test was used if the covariate of interest had zero membership in one or more categories of a given variable). Statistically significant variables identified in the univariate analyses described above were incorporated as independent variables into multivariable logistic regression analyses that were used to identify independent predictors of membership in the adapted and maladapted groups.

Multiple linear regression models were used to examine the relationship between biomarkers of interest (dependent variables) and adaptation/maladaptation status among Aim 2 survey respondents. Biomarker data were obtained from each participant's most recent clinical exam. Adjusted (least squares or LS) means of each biomarker were compared statistically between the adapted and maladapted LCA groups. Each model was adjusted for age, sex, race, BMI, tobacco use, total alcoholic beverages consumed per week, education, physical activity, marital status, and antidepressant use.

Outcome Aim 2

Demographic characteristics of the Aim 2 survey respondents (N=120) are displayed in Table 2.1. The mean age was 47±9 years among evening/night workers (n=67), and 52±9 among day workers (n=53). Relative to evening/night workers, those working day shifts tended to have a greater proportion of females (51% vs. 21%), African American (or another minority race, 25% vs. 6%), police force service exceeding 20 years (72% vs. 48%), and a higher rank (30% vs. 22% detective/executive/other, Table 2.1).

Descriptions of the LCA symptom indicator variables and fit statistics for the LCA modeling results are presented in supplemental Tables A.2.1 and A.2.2, respectively (see Appendix Aim 2, below). For the police specific model, the 2-group and 3-group models both had low BICs relative to other models. For the general symptom model, the 2-group model had the lowest BIC. In addition, for all the models with positive degrees of freedom, none of the chi-squared goodness of fit tests were statistically significant. Thus, for both the general and police specific models, the 2-group model was selected for further analysis (Table A.2.2). Figures 2.1 (police specific) and 2.2 (general) summarize results for each LCA model with officers grouped according to LCA-predicted adaptation/maladaptation symptoms. Item response probabilities are displayed for poor symptoms among each indicator variable included in the models. Both models predicted two groups with distinct patterns of symptoms that are indicative of adaptation and maladaptation to atypical work hours.

Tables 2.2a-2.2d present results of univariate analyses comparing sociodemographic, behavioral, lifestyle, psychosocial, personal/familial and occupational variables of interest between the adapted and maladapted LCA groups. Among the Aim 2 survey respondents, there were n=17 maladapted officers identified by the LCA using the police specific model (14%), and using the general model there were n=10 maladapted officers (8%). There were no statistically significant differences in mean response scores to the direct questions about shiftwork adaptation (How adapted are you to your shift schedule?, How content are you with your work schedule?, Is your performance optimal on your current schedule? Table 2.2a). Frequency distributions of answers to the shiftwork adaptation questions are presented by adaptation/maladaptation status for each LCA model (general and police-specific) in Figures A.2.1-A.2.6 (Appendix Aim 2). Those with LCA-derived shiftwork maladaptation were more likely to work evenings or nights (general model, 100% maladapted, $p<0.01$), and they had a greater average number of shift changes both in the police specific and general models (Table 2.2a). The average number of shift changes among maladapted officers (police specific: 128±132 hrs, general: 142±133 hrs) was nearly two times greater than shift changes among adapted workers (police specific: 72±79 hrs, $p=0.04$; general: 75±84 hrs, $p=0.04$, Table 2.2a). There was a tendency for shiftwork maladaptation to be associated with higher scores for poor sleep quality, although the differences were not statistically significant (e.g., general symptom model, $p=0.09$, Table 2.2b). Maladapted workers also had less hardiness and familial organization, and more family conflict relative to adapted workers (Table 2.2c). Maladapted personnel identified using the police specific model were also more likely to have: a greater average number of adverse childhood events, more daily police hassles, lower scores for 'reward' on the ERIS (Effort Reward Imbalance Scale), greater impact of events (IESR) scores, less supervisor and coworker support, higher scores on several burnout subscales (exhaustion, cynicism, professional efficacy), and more work-family imbalance (Table 2.2d). Those identified as maladapted using the general model were more likely to have: a greater average number of adverse childhood events, higher impact of events (IESR) scores, more work related injuries sustained within the past month, higher scores on burnout (exhaustion, cynicism, professional efficacy), and lower scores for mindfulness (Kentucky Inventory of Mindfulness Scale or KIMS) (Table 2.2d).

These results indicated that the LCA-derived categories objectively characterized adaptation/maladaptation status, and that the direct adaptation questions may have been susceptible to response bias (i.e., personnel did not want to admit that they were maladapted). Therefore, the LCA-derived grouped were used in subsequent analyses.

Table 2.3 presents the results of combined multivariable analyses for factors that were associated with shiftwork adaptation/maladaptation that were identified in Tables 2.2a-d. Only hardiness subscales were used in this analysis to avoid multicollinearity. For the police specific shiftwork adaptation model, greater familial organization (OR: 1.59, CI: 1.05-2.41), and greater supervisor support (OR: 1.36, CI: 1.01-1.83) was independently associated with higher odds of shiftwork adaptation, whereas in the general model adaptation was associated with greater familial control (OR: 2.18, CI: 0.97-4.88, p=0.06) and less burnout (Maslach cynicism subscale, OR: 0.80, CI: 0.65-0.98, Table 2.3).

Rankings for shiftwork adaptation strategies ('What strategies are most important to you for adapting to your work schedule?') are presented by dominant work shift in Figure 2.3. Police personnel responding to the Aim 2 survey were asked to rank their top five most important strategies with higher scores representing more important strategies. Strategies related to sleep were the most prevalent for all three work shifts, surpassing rankings for all other strategies by 2-3 fold. The importance of 'getting the right amount of sleep' was ranked higher among those working nights relative to those working evenings or day shifts. Other highly ranked strategies included: appropriate sleep timing, and having an appropriate sleep environment, proper diet, and adequate exercise. Figures 2.4 and 2.5 present the rankings of shiftwork coping strategies among those classified as either adapted or maladapted to shiftwork using the police specific and general LCA models, respectively. Strategies related to sleep were predominant in both the adapted and maladapted groups. Some differences were noted, including more frequent use of sleep aids (general model) and caffeinated beverages (general and police specific) among maladapted officers relative to those who were adapted.

Figure 2.6 presents responses to questions addressing work schedule impacts among Aim 2 respondents grouped by dominant work shift. Higher rankings represent greater satisfaction with the amount of time officers had for personal activities such as hobbies/sports, family/friends, cultural/social events, and other personal activities. As expected, rankings were higher for those working days and lower among those working evenings and nights (Fig. 2.6). Rankings of work schedule impacts were generally similar among participants grouped by adaptation/maladaptation status (Figure 2.7, police specific model, and Figure 2.8, general model).

The relationship between adaptation/maladaptation and chronic disease indicators of interest are presented in Tables 2.4-2.8 after adjustment for age, gender, race, tobacco use, BMI, alcoholic drinks per week, education, physical activity, marital status, and antidepressant use. Maladapted workers had elevated levels of the inflammatory cytokine, IL-6 (p=0.02, general symptom model, Table 2.4), as well as elevated triglycerides (p=0.07), and cholesterol:HDL ratio (p=0.01), more metabolic syndrome components (p=0.07), and greater metabolic syndrome severity scores (p=0.01) relative to adapted workers (police specific model, Table 2.6).

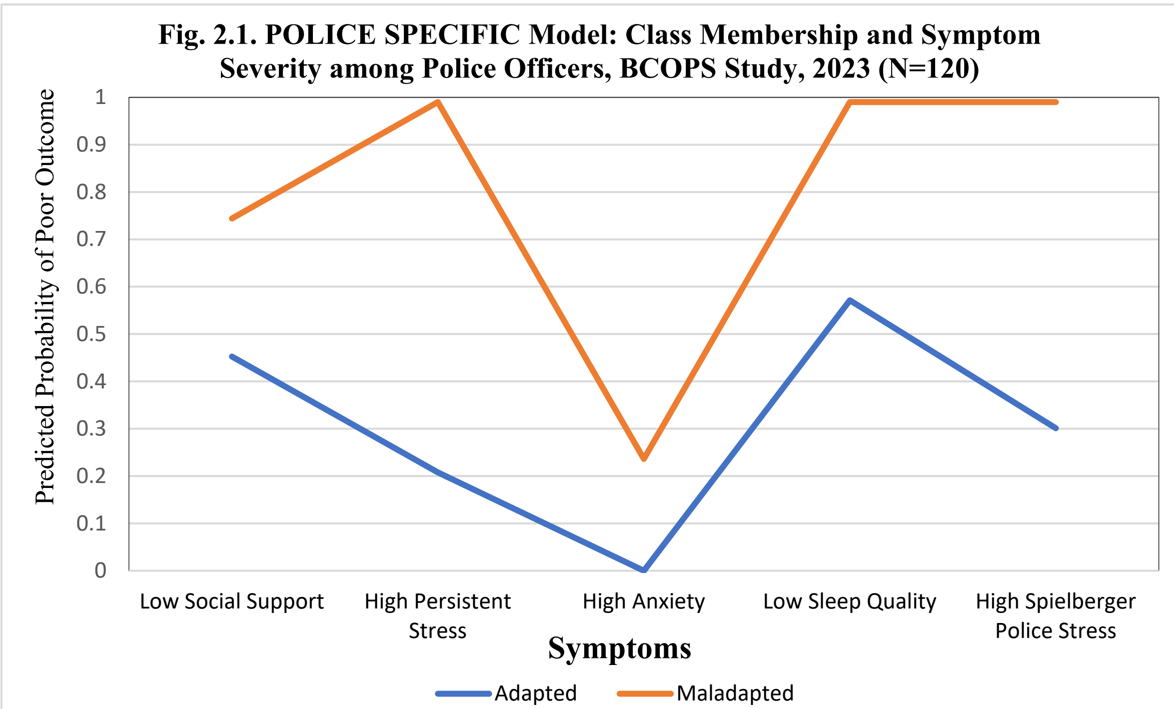

Figure 2.1. Results of latent class analysis (Police specific model) showing class membership and item-response probabilities (1=high or 100% probability of elevated symptom severity) among officers in the BCOPS cohort (Buffalo, NY, USA).

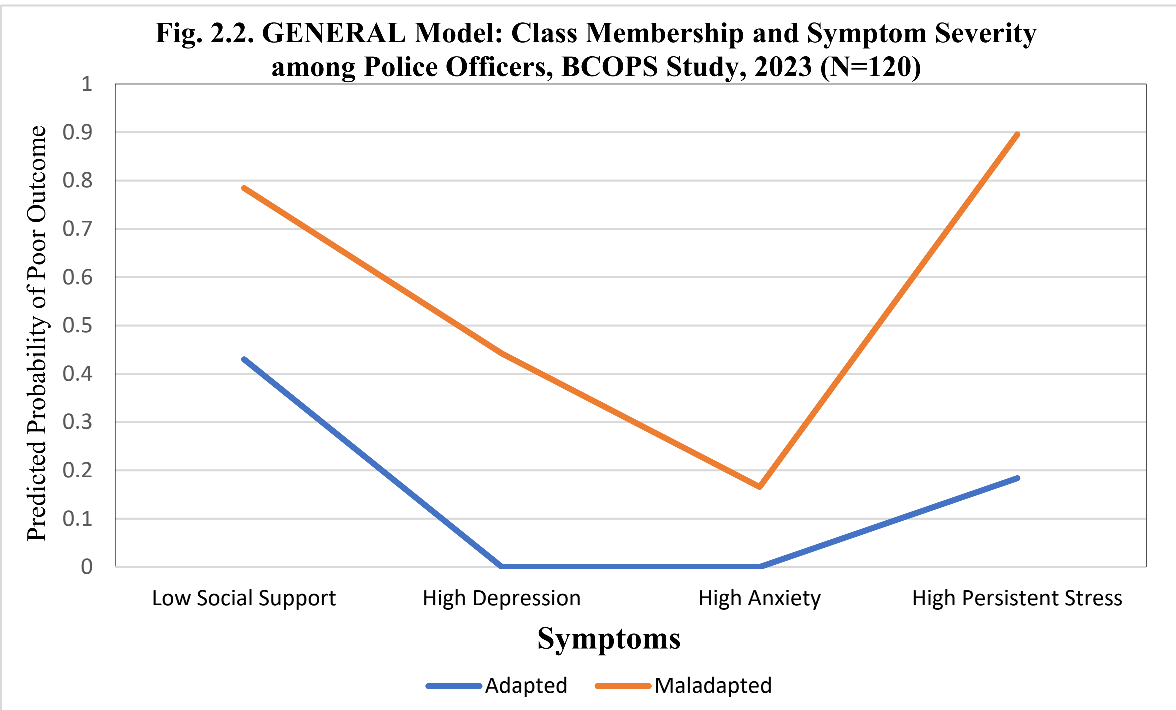

Figure 2.2. Results of latent class analysis (General model) showing class membership and item-response probabilities (1=high or 100% probability of elevated symptom severity) among officers in the BCOPS cohort (Buffalo, NY, USA).

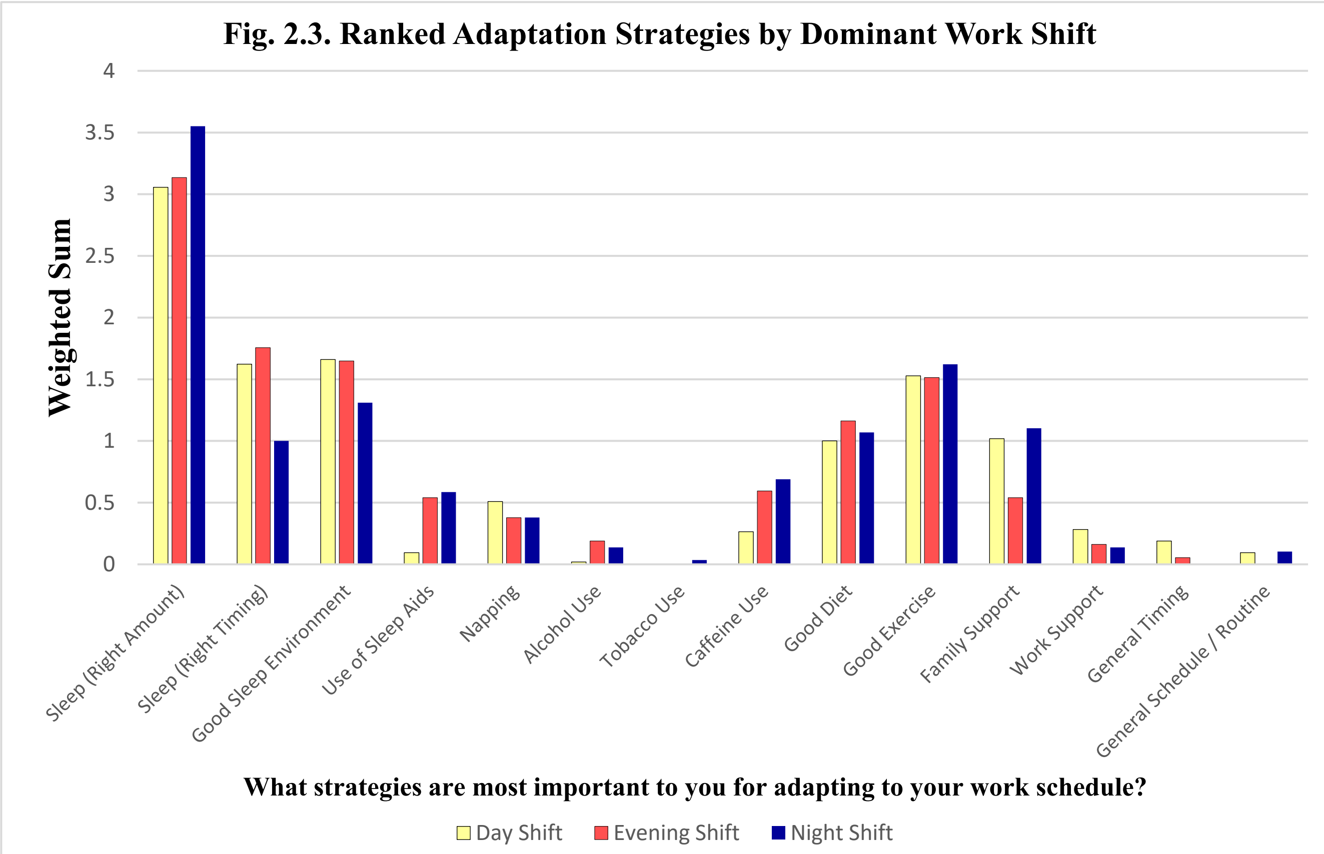

Figure 2.3. Aim 2 participants were asked to rank their top five most important strategies. Weighted sums were calculated for each participant and then averaged within each shift. Higher scores represent more important strategies. Police officers in the BCOPS cohort. (Buffalo, NY, USA, 2023, N=120).

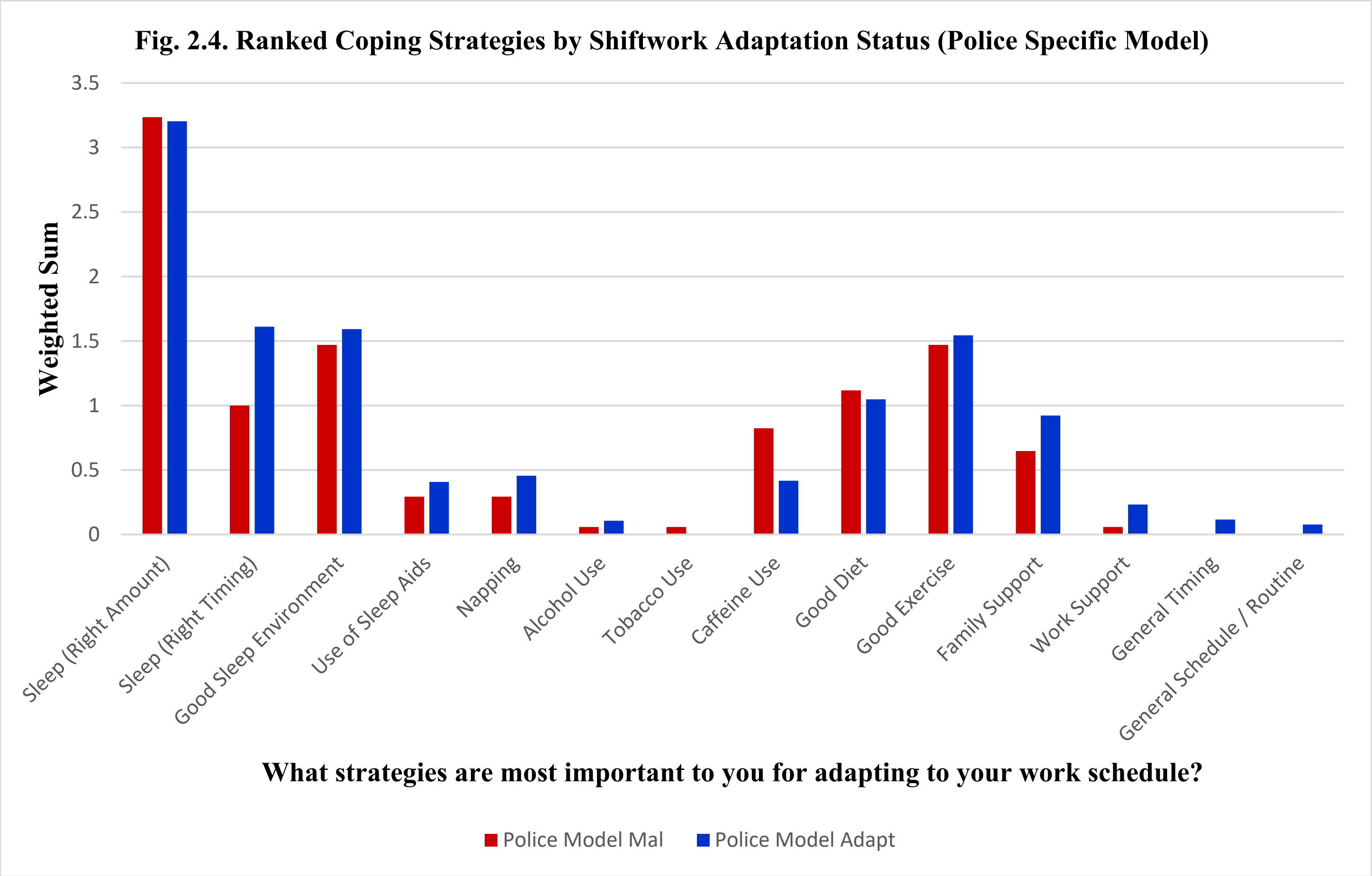

Figure 2.4. Aim 2 participants were asked to rank their top five most important strategies. Weighted sums were calculated for each participant and then averaged within each group. Higher scores represent more important strategies. Police officers in the BCOPS cohort. (Buffalo, NY, USA, 2023, N=120). Mal: maladapted. Adapt: adapted.

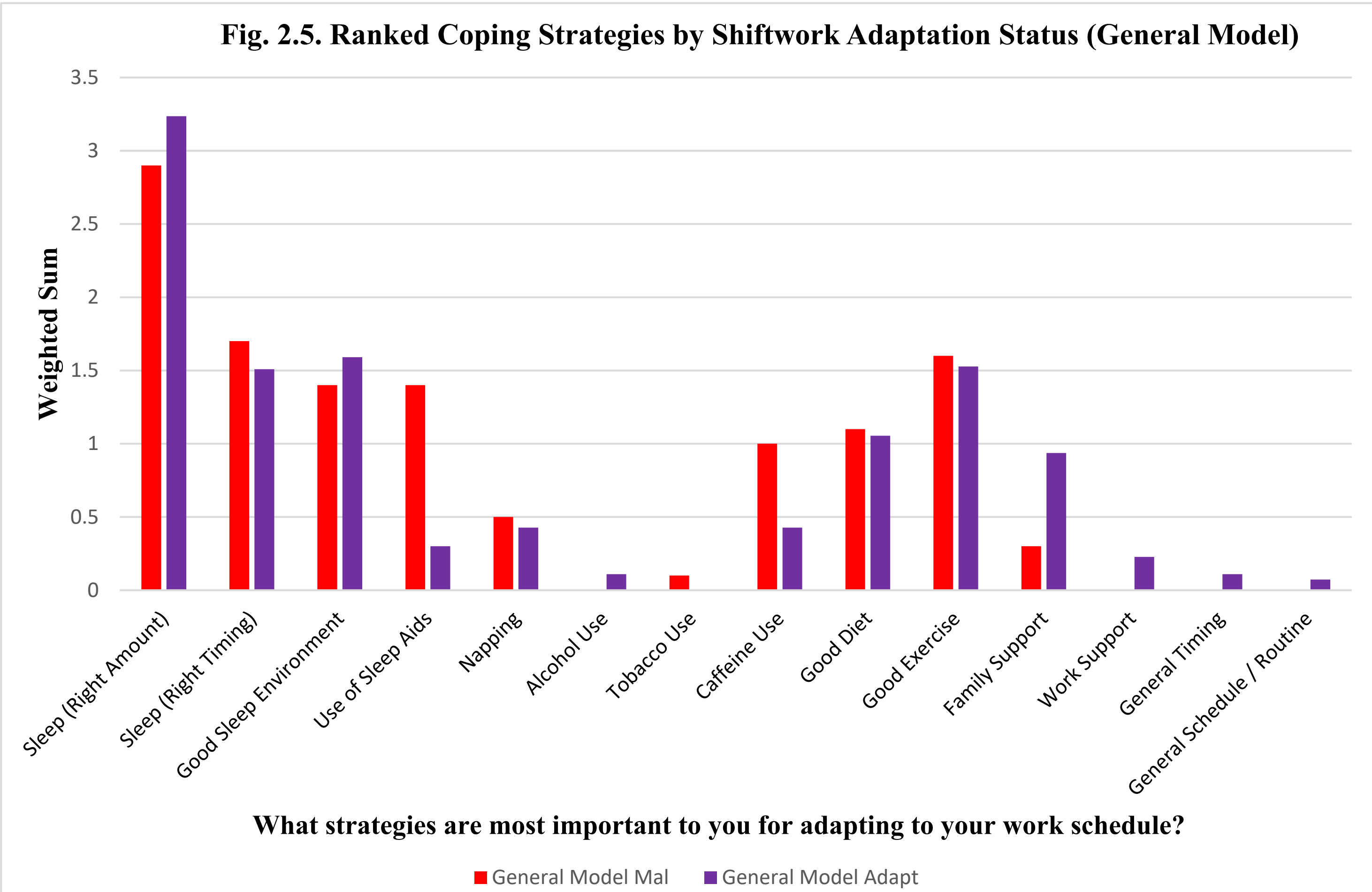

Figure 2.5. Aim 2 participants were asked to rank their top five most important strategies. Weighted sums were calculated for each participant and then averaged within each group. Higher scores represent more important strategies. Police officers in the BCOPS cohort. (Buffalo, NY, USA, 2023, N=120). Mal: maladapted. Adapt: adapted.

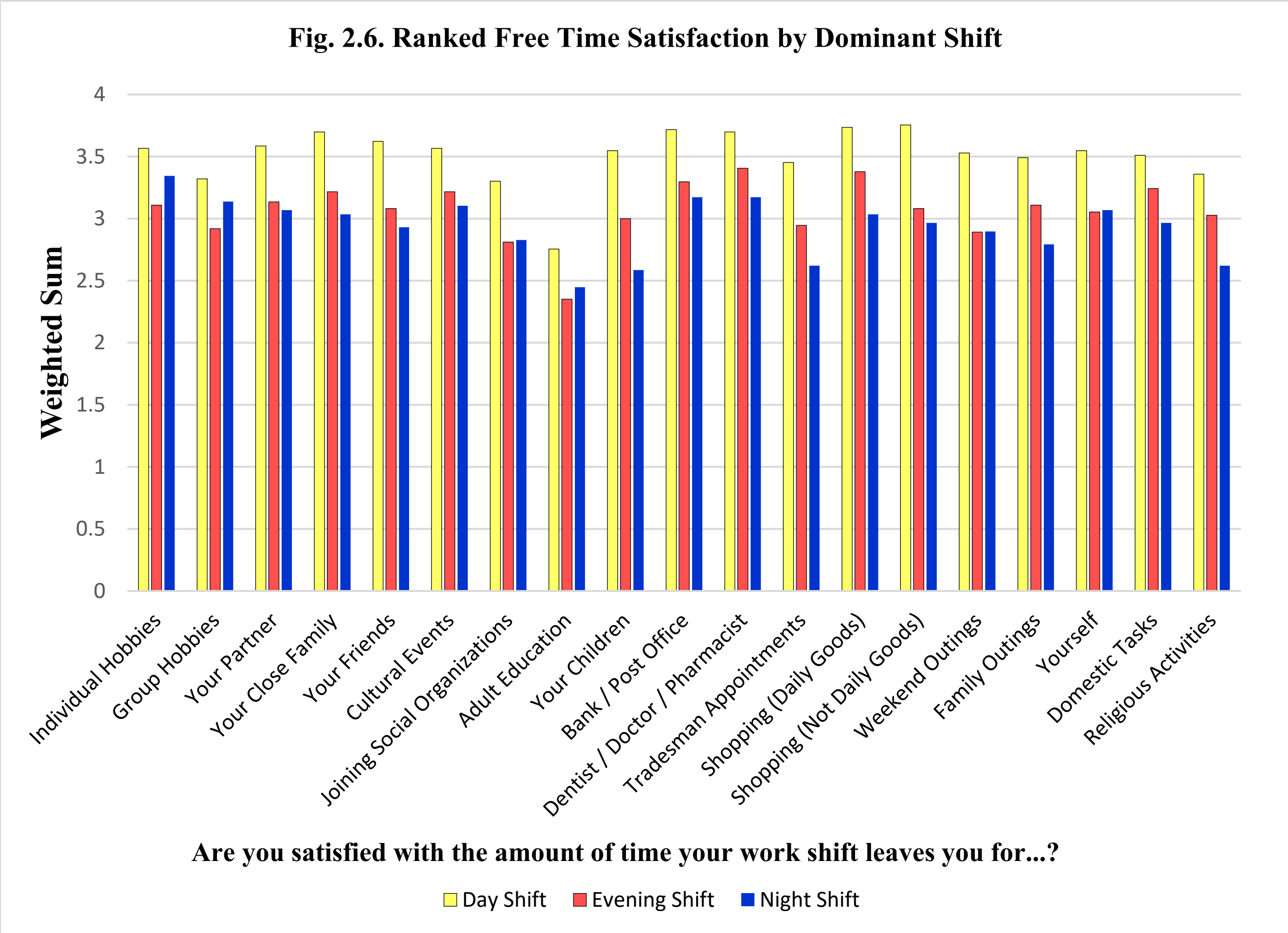

Figure 2.6. Aim 2 participants ranked each activity, weighted sums were calculated for each participant and averaged within each group. Higher scores represent greater satisfaction. Police officers in the BCOPS cohort. (Buffalo, NY, USA, 2023, N=120).

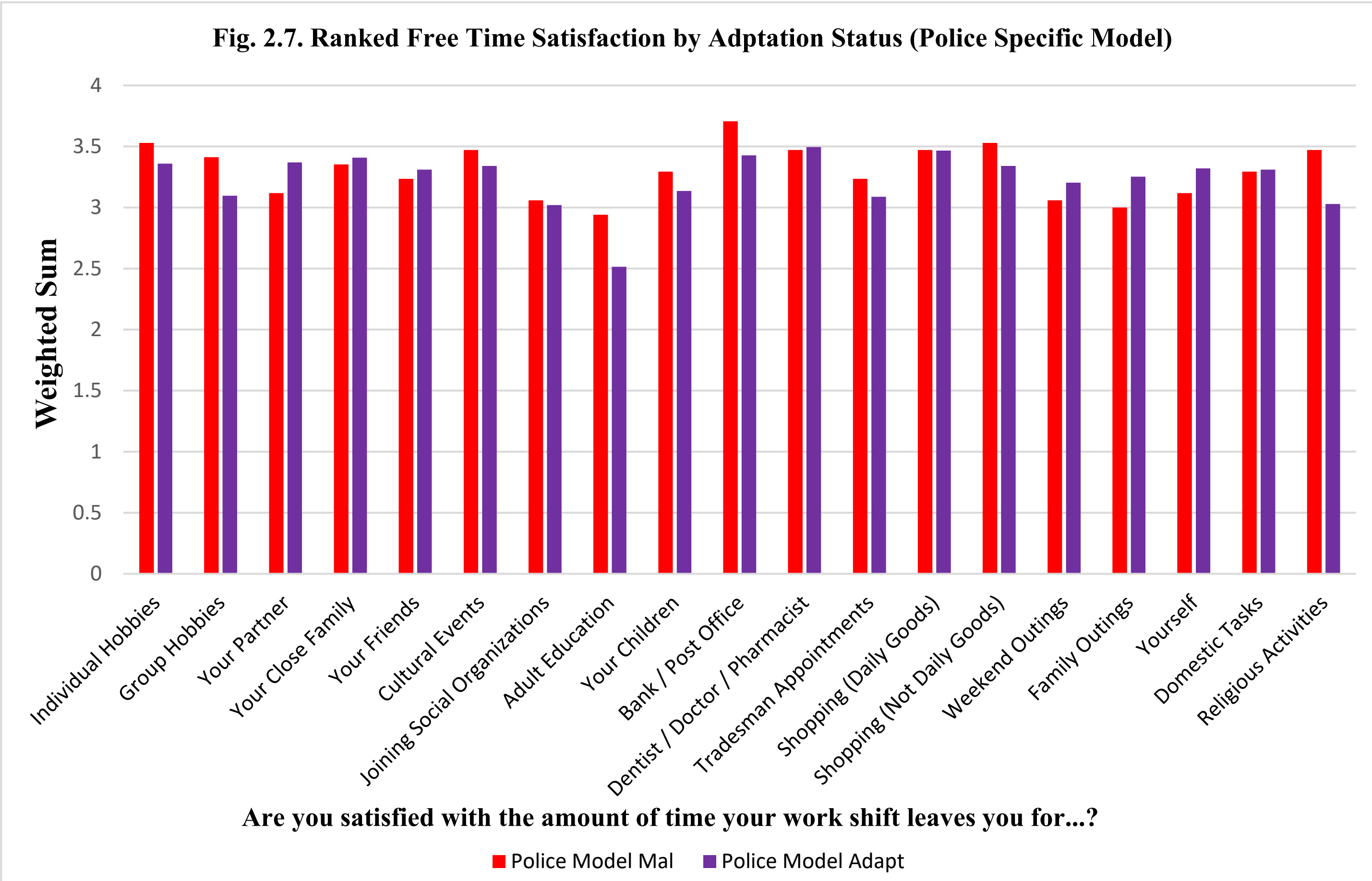

Figure 2.7. Aim 2 participants ranked each activity, weighted sums were calculated for each participant and averaged within each group. Higher scores represent greater satisfaction. Police officers in the BCOPS cohort. (Buffalo, NY, USA, 2023, N=120).

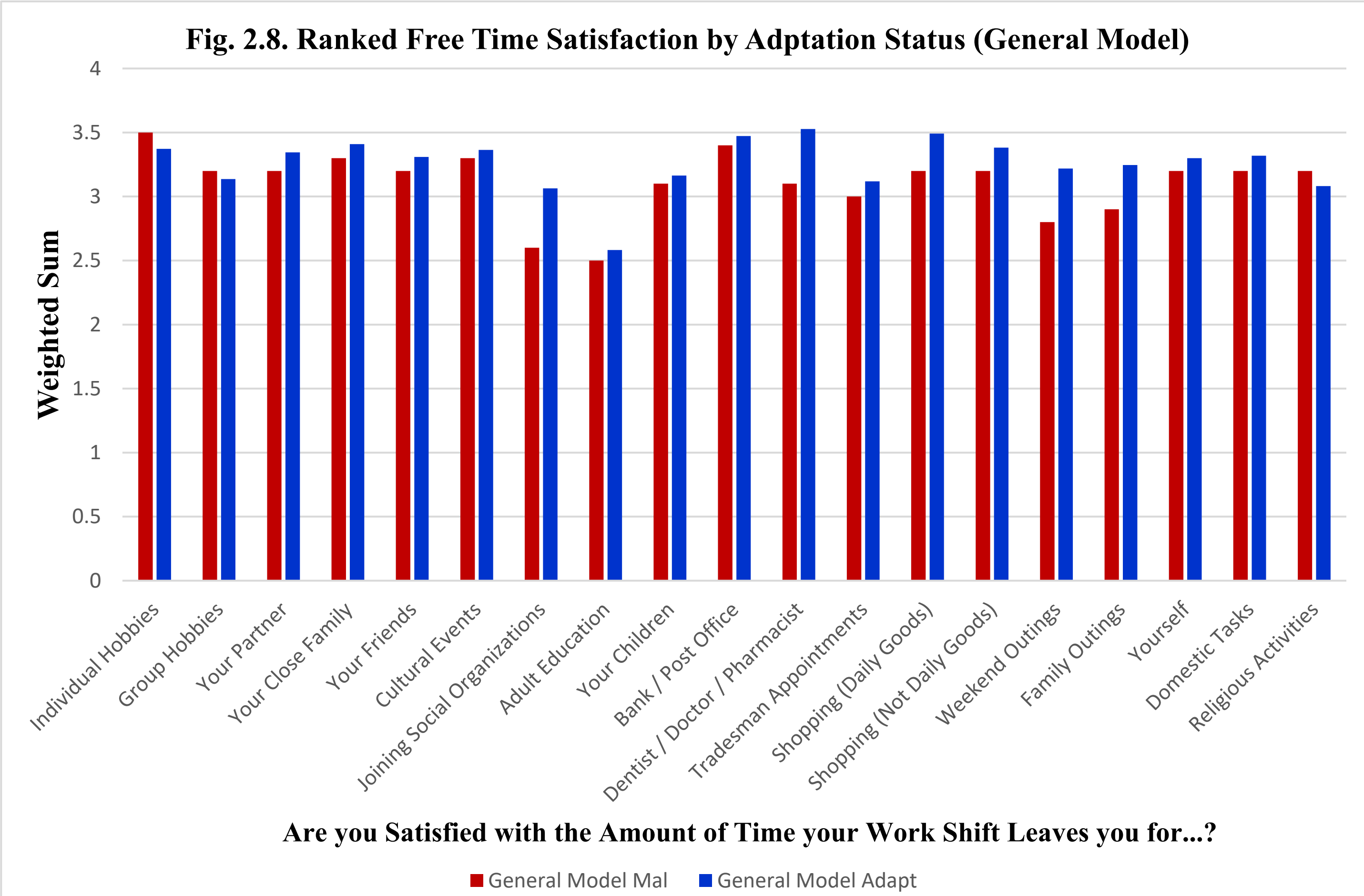

Figure 2.8. Aim 2 participants ranked each activity, weighted sums were calculated for each participant and averaged within each group. Higher scores represent greater satisfaction. Police officers in the BCOPS cohort. (Buffalo, NY, USA, 2023, N=120).

Table 2.1. Demographic Characteristics of Study Participants, BCOPS Study, Buffalo, NY, USA, 2023 (N=120)

Characteristics	Evening and Night Workers (n=67)[a]				Day Workers (n=53)[a]			
	N	%	Mean	SD	N	%	Mean	SD
Age (yrs)	--	--	47	9	--	--	52	9
Body Mass Index (kg/m^2)	--	--	29	5	--	--	29	4
Sex								
Female	14	21	--	--	27	51	--	--
Male	53	79	--	--	26	49	--	--
Race								
European American	63	94	--	--	40	75	--	--
African American/Other	4	6	--	--	13	25	--	--
Marital Status								
Single	12	18	--	--	7	13	--	--
Married	47	70	--	--	38	72	--	--
Divorced	8	12	--	--	8	15	--	--
Education (yrs)								
Up to High School ≤12	6	9	--	--	3	6	--	--
College <4	32	48	--	--	23	43	--	--
College ≥4	29	43	--	--	27	51	--	--
Rank								
Police Officer	35	52	--	--	25	47	--	--
Sergeant/Lieutenant/Captain	17	25	--	--	12	23	--	--
Detective/Executive/Other	15	22	--	--	16	30	--	--
Years of Police Service (yrs)								
0-9	16	24	--	--	8	15	--	--
10-14	2	3	--	--	1	2	--	--
15-19	17	25	--	--	6	11	--	--
20+	32	48	--	--	38	72	--	--

Column percentages not totaling 100% are due to rounding or missing data. [a] 19 evening/night shift and 20 day workers had missing values for one or more variables. SD: standard deviation.

Table 2.2a. Factors Associated with Shiftwork Adaptation, BCOPS Study, Buffalo, NY, USA, 2023 (N=120)

Characteristics	Police Specific Model							General Symptom Model						
	Adapted (n=103)			Maladapted (n=17)			p	Adapted (n=110)			Maladapted (n=10)			p
	%	Mean	SD	%	Mean	SD		%	Mean	SD	%	Mean	SD	
Age (yrs)	--	50	11	--	47	8	0.31	--	49	11	--	49	9	0.90
Body Mass Index (kg/m^2)	--	29	4	--	30	4	0.59	--	29	4	--	29	6	0.78
Body Mass Index Groups														
≤30	58	--	--	53	--	--	0.68	58	--	--	50	--	--	0.62
>30	42	--	--	47	--	--		42	--	--	50	--	--	
Race														
European American	70	--	--	88	--	--	0.13	70	--	--	100	--	--	0.06
African American/Other	30	--	--	12	--	--		30	--	--	0	--	--	
Sex														
Male	65	--	--	71	--	--	0.66	65	--	--	80	--	--	0.33
Female	35	--	--	29	--	--		35	--	--	20	--	--	
Marital Status														
Not Married	43	--	--	29	--	--	0.31	42	--	--	30	--	--	0.47
Married	57	--	--	71	--	--		58	--	--	70	--	--	
Education														
College	41	--	--	35	--	--	0.67	41	--	--	30	--	--	0.50
No College	59	--	--	65	--	--		59	--	--	70	--	--	
No. of Sick Days	--	0.8	0.8	--	0.7	0.7	0.82	--	0.8	0.8	--	0.6	0.7	0.52
No. of Shift Changes	--	72	79	--	128	132	**0.04**	--	75	84	--	142	133	**0.04**
Dominant Shift														
Days	47	--	--	29	--	--	0.19	48	--	--	0	--	--	**0.002**
Evenings/Nights	53	--	--	71	--	--		52	--	--	100	--	--	
Overtime Hours														
≤10	68	--	--	41	--	--	**0.05**	63	--	--	60	--	--	0.84
>10	32	--	--	59	--	--		37	--	--	40	--	--	
Adapted to Shift[a]	--	8.3	1.8	--	8.3	1.4	0.98	--	8.4	1.7	--	7.8	2.8	0.34
Content with Shift[b]	--	4.1	1.0	--	4.1	1.1	0.88	--	4.1	1.0	--	4.1	1.3	0.96
Optimal Performance[c]	--	4.0	0.8	--	3.7	0.9	0.20	--	4.0	0.8	--	3.8	1.1	0.43

Each characteristic was analyzed as a separate univariate model. [a] 'How adapted are you to your shift schedule' (scale: 1-10)? [b] 'How content are you with your work schedule' (scale: 1-5)? [c] 'Is your performance optimal on your current schedule' (scale: 1-5)? Greater values represent better adaptation, more satisfaction, or better performance.

Table 2.2b. Factors Associated with Shiftwork Adaptation, BCOPS Study, Buffalo, NY, USA, 2023 (N=120)

Characteristics	Police Specific Model			General Symptom Model		
	Adapted (n=103)	Maladapted (n=17)	p	Adapted (n=110)	Maladapted (n=10)	p
Years of Police Service (%)						
0-19	40.5	47.1	0.62	40.7	50.0	0.57
20+	59.5	52.9		59.3	50.0	
Rank (%)						
Below Detective	78.6	70.6	0.46	77.3	80.0	0.84
Detective/Executive/Other	21.4	29.4		22.7	20.0	
Military Service (%)						
No	79.8	76.5	0.76	76.9	100	0.11
Yes	20.2	23.5		23.1	0	
Work Activity (%)						
High	43.7	64.7	0.11	44.5	70.0	0.14
Low-Moderate	56.3	35.3		55.5	30.0	
Tobacco Use(%)						
Never / Former	89.3	94.1	0.55	90.9	80.0	0.29
Current	10.7	5.9		9.1	20.0	
Number of Drinks per Week (%)						
High (Q 4)	24.4	23.5	0.94	25.8	10.0	0.29
Low (Q 1-3)	75.6	76.5		74.2	90.0	
Servings of food cooked in fat / day (%)						
High (Q 4)	8.3	17.6	0.25	8.8	20.0	0.27
Low (Q 1-3)	91.7	82.4		91.2	80.0	
Servings of vegetables / day (%)						
High (Q 4)	22.6	5.9	0.15	20.9	10.0	0.43
Low (Q 1-3)	77.4	94.1		79.1	90.0	
Servings of fruit / day (%)						
High (Q 4)	19.0	5.9	0.21	17.6	10.0	0.55
Low (Q 1-3)	81.0	94.1		82.4	90.0	
Global Sleep Quality Score (PSQI) (%)[a]						
Poor	--	--	--	59.1	90.0	0.09
Good	--	--		40.9	10.0	

Each characteristic was analyzed as a separate univariate model. Quartiles of food servings are derived from the total sample of 159 survey respondents. Poor sleep quality was defined as a Pittsburg Sleep Quality Index (PSQI) global score of >5. a - The PSQI p-value was not calculated in the Police Specific model because the variable was used in the latent class analysis.

Table 2.2c. Factors Associated with Shiftwork Adaptation, BCOPS Study, Buffalo, NY, USA, 2023 (N=120)

Characteristic	**Police Specific Model**					**General Symptom Model**				
	Adapted (n=103)		Maladapted (n=17)		p-value	Adapted (n=110)		Maladapted (n=10)		p-value
	Mean	SD	Mean	SD		Mean	SD	Mean	SD	
Hardiness Total Score (DRS)[a]	29.5	6.1	25.0	6.5	**0.01**	29.8	5.7	19.9	5.3	**<0.01**
Commitment[a]	10.6	2.6	8.4	2.7	**<0.01**	10.6	2.4	6.4	2.5	**<0.01**
Challenge[a]	8.8	2.6	7.5	3.3	0.09	8.8	2.7	6.3	2.7	**0.01**
Control[a]	10.2	2.5	9.2	2.1	0.11	10.4	2.2	7.2	2.5	**<0.01**
Family Conflict (FES)[b]	2.1	1.9	3.3	2.7	**0.04**	2.3	2.0	2.4	2.6	0.87
Family Independence (FES)[b]	7.1	1.4	6.4	1.4	0.06	7.0	1.4	7.4	1.6	0.34
Active-Recreational Orientation[b]	5.9	2.1	6.3	1.3	0.49	6.1	1.9	5.4	2.5	0.31
Familial Organization (FES)[b]	6.9	1.9	4.6	2.2	**<0.01**	6.8	2.0	4.6	2.5	**0.01**
Familial Control (FES)[b]	4.8	1.8	5.6	1.8	0.12	5.0	1.8	4.6	2.0	0.48
Global Sleep Quality Score (PSQI)	--	--	--	--	--	1.4	0.5	1.1	0.3	0.09

[a] Dispositional Resilience Scale (DRS). Higher scores represent more commitment, control, challenge, or hardiness. FES: Family Environment Scale. [b] Higher scores indicate a higher degree of perceived family interaction. Each characteristic was analyzed as a separate univariate model. SD: standard deviation. DRS: Dispositional Resilience Scale.. PSQI = Pittsburgh Sleep Quality Index.

Table 2.2d. Factors Associated with Shiftwork Adaptation, BCOPS Study, Buffalo, NY, USA, 2023 (N=120)

Characteristics	**Police Specific Model**					**General Symptom Model**				
	Adapted (n=103)		Maladapted (n=17)			Adapted (n=110)		Maladapted (n=10)		
	Mean	SD	Mean	SD	p	Mean	SD	Mean	SD	p
No. of Adverse Childhood Events	1.0	1.3	2.6	2.8	**<.01**	1.2	1.6	2.6	2.3	**0.02**
Alcoholic Beverages (per day)	0.8	0.9	0.8	0.8	0.82	0.8	0.8	1.0	1.3	0.41
No. of Police Daily Hassles	103	59	139	70	**0.05**	107	62	139	71	0.19
Effort (ERIS)	12	3	13	4	0.27	12	3	12	3	0.60
Reward (ERIS)	52	3	48	8	**0.01**	52	5	50	5	0.50
Effort : Reward Ratio (ERIS)	0.4	0.1	0.5	0.3	0.08	0.4	0.2	0.5	0.1	0.74
Impact of Events (IESR)	6	8	13	14	**0.02**	7	7	15	18	**0.03**
No. of Work Injuries Sustained (past month)	1	2	2	1	0.19	1	1	3	1	**0.01**
Job Content: Skill Discretion	33	4	32	5	0.19	33	4	31	6	0.15
Job Content: Decision Authority	37	5	36	6	0.27	37	5	35	7	0.31
Job Content: Decision Latitude	70	8	67	11	0.19	70	8	66	13	0.16
Job Content: Psychological Demand	30	4	32	5	0.16	30	4	32	5	0.52
Job Content: Physical Exertion	6	2	6	2	0.49	6	2	5	2	0.14
Job Content: Physical Loads	4	1	4	2	0.94	4	1	4	2	0.59
Job Content: Physical Demand	10	2	9	3	0.63	10	2	9	4	0.49
Job Content: Job Insecurity	4	1	4	1	0.21	4	1	3	1	0.44
Job Content: Supervisor Support	12	2	9	3	**<.01**	11	3	10	4	0.19
Job Content: Coworker Support	13	2	11	1	**0.01**	12	2	12	2	0.91
Burnout: Exhaustion	9	6	15	9	**<.01**	9	7	19	9	**<.01**
Burnout: Cynicism	10	8	18	8	**<.01**	10	8	25	6	**<.01**
Burnout: Professional Efficacy	30	6	26	7	**0.03**	30	6	22	4	**0.01**
KIMS: Observing	32	8	32	6	0.92	32	8	31	7	0.57
KIMS: Describing	30	5	27	5	0.09	30	5	24	4	**<.01**
KIMS: Acting with Awareness	34	5	31	4	0.06	34	5	31	4	**0.04**
KIMS: Accepting without Judgement	37	6	34	5	0.07	37	6	31	6	**0.01**
Perfectionism: Self-Oriented	66	15	62	17	0.32	66	15	61	21	0.29

Table 2.2d. Factors Associated with Shiftwork Adaptation, BCOPS Study, Buffalo, NY, USA, 2023 (N=120)

Characteristics	**Police Specific Model**					**General Symptom Model**				
	Adapted (n=103)		Maladapted (n=17)			Adapted (n=110)		Maladapted (n=10)		
	Mean	SD	Mean	SD	p	Mean	SD	Mean	SD	p
Perfectionism: Other-Oriented	58	11	58	10	0.78	59	10	57	13	0.57
Perfectionism: Socially Prescribed	47	13	51	13	0.17	47	12	53	17	0.19
Sum of Social Network (Q2-11)	1.6	1.5	2.3	1.7	0.10	1.7	1.6	2.1	1.3	0.40
Vitamin B12 (IU)	5.4	3.6	5.1	2.4	0.71	5.5	3.5	4.6	2.5	0.43
Vitamin B6 (IU)	2.0	0.8	2.0	0.7	0.89	2.0	0.8	1.7	0.6	0.21
Vitamin C (IU)	112	68	130	78	0.33	118	72	89	41	0.22
Vitamin D (IU)	6.1	4.6	6.5	5.7	0.77	6.3	4.8	5.5	4.7	0.65
Vitamin E (IU)	17	13	17	9	0.89	17	12	23	16	0.15
Vitamin K (IU)	143	102	116	67	0.30	142	100	104	55	0.24
Sun Exposure (hrs on day off)	3.5	2.5	3.9	2.9	0.57	3.7	2.6	2.9	1.7	0.38
Work-Family Imbalance	16	7	21	9	**0.03**	17	8	18	10	0.64
Family-Work Imbalance	11	6	13	6	0.28	11	6	14	6	0.19

Each characteristic was analyzed as a separate univariate model. ERIS – Effort Reward Imbalance Scale. IESR – Impact of Event Scale Revised. Job Content – Job Content Questionnaire. Burnout – Maslach Burnout Inventory. KIMS – Kentucky Inventory of Mindfulness Scale. Perfectionism – Multidimensional Perfectionism Scale. Work-Family & Family-Work Imbalances taken from the Work Family Scale (Netemeyer 1996).[33]

Table 2.3. Factors Associated with Shiftwork Adaptation Multivariable Analysis, BCOPS Study, 2023 (N=120)[*]

Characteristics	Odds Ratio	95% CI	p-value
Police Specific Model			
Hardiness – Commitment[a]	0.98	0.63-1.53	0.93
Familial Organization[b]	1.59	1.05-2.41	**0.03**
No. of Adverse Childhood Experiences	0.86	0.53-1.40	0.54
Job Content: Supervisor Support[c]	1.36	1.01-1.83	**0.04**
Maslach Burnout: Exhaustion[d]	0.93	0.80-1.07	0.30
Maslach Burnout: Cynicism[d]	0.95	0.84-1.09	0.47
General Symptom Model			
Hardiness – Commitment[a]	1.06	0.55-2.07	0.85
Familial Control[b]	2.18	0.97-4.88	0.06
KIMS – Describing[e]	1.09	0.86-1.38	0.47
Maslach Burnout: Exhaustion[d]	0.90	0.75-1.07	0.22
Maslach Burnout: Cynicism[d]	0.80	0.65-0.98	**0.03**

[*] The outcome modeled is the odds of being adapted to shiftwork as defined by the LCA symptoms (see methods). For continuous variables, the odds ratio represents a one-unit change in the predictor variable. For example, the odds of being adapted to shiftwork increase by 2% with a one-unit increase in the hardiness commitment score. Maladapted Group (referent). CI: confidence interval. [a] Higher scores correspond to greater hardiness. [b] Higher scores indicate a higher degree of perceived family interaction. [c] Higher scores indicate a greater level of supervisor support. [d] Higher scores indicate more severe burnout symptoms. [e] Higher scores indicate a higher level of mindfulness.

Table 2.4. Inflammation Measures by Shiftwork Adaptation Group, BCOPS Study, 2023 (N=120)[a]

Inflammation/Immune Mediator	Police Specific Model				
	Adapted (n=103)		Maladapted (n=17)		p-value A vs. M
	Mean	SE	Mean	SE	
C-Reactive Protein ln(mg/L)	0.3	0.3	0.1	0.4	0.67
Interleukin-6 ln(pg/mL)	0.5	0.2	0.8	0.2	0.16
Tumor Necrosis Factor alpha (pg/mL)	5.4	0.8	5.8	1.0	0.63
White Blood Cells (10^9/L)	5.9	0.4	5.7	0.5	0.55
ICAM-1 (ng/mL)	155	25	135	30	0.41
Fibrinogen (mg/dL)	426	24	380	29	0.06
Inflammation/Immune Mediator	**General Symptom Model**				
	Adapted (n=110)		Maladapted (n=10)		p-value A vs. M
	Mean	SE	Mean	SE	
C-Reactive Protein ln(mg/L)	0.2	0.3	0.4	0.5	0.67
Interleukin-6 ln(pg/mL)	0.6	0.2	1.0	0.3	**0.02**
Tumor Necrosis Factor alpha (pg/mL)	5.5	0.8	6.5	1.2	0.32
White Blood Cells (10^9/L)	5.8	0.4	6.3	0.7	0.45
ICAM-1 (ng/mL)	151	25	129	39	0.51
Fibrinogen (mg/dL)	413	24	427	39	0.66

[a] Least squares mean ± standard error of the mean. Models adjusted for age, gender, race, tobacco use, BMI, alcoholic drinks per week, education, physical activity, marital status, and antidepressant use. p-values for comparisons between adapted and maladapted categories. Data for CRP and IL6 were log-transformed because values were not normally distributed. Abbreviations: SE: standard error of the mean. A: Adapted. M: Maladapted. ln = natural logarithm. BMI = body mass index (kg/m^2).

Table 2.5. Endocrine Measures by Shiftwork Adaptation Group, BCOPS Study, 2023 (N=120)[a]

Endocrine Measures	Police Specific Model				
	Adapted (n=103)		Maladapted (n=17)		p-value
	Mean	SE	Mean	SE	A vs. M
Thyroid Stimulating Hormone (uIU/L)	2.5	0.4	2.0	0.5	0.20
Triiodothyronine (nmol/L)	1.7	0.1	1.7	0.1	0.68
Insulin ln(pg/mL)	5.8	0.2	5.9	0.3	0.61
Leptin ln(pg/mL)	9.3	0.2	9.4	0.2	0.52

Endocrine Measures	General Symptom Model				
	Adapted (n=110)		Maladapted (n=10)		p-value
	Mean	SE	Mean	SE	A vs. M
Thyroid Stimulating Hormone (uIU/L)	2.3	0.4	2.6	0.6	0.60
Triiodothyronine (nmol/L)	1.7	0.1	1.9	0.2	0.18
Insulin ln(pg/mL)	5.8	0.2	5.7	0.4	0.70
Leptin ln(pg/mL)	9.3	0.2	9.6	0.3	0.16

[a] Least squares mean ± standard error of the mean. Models adjusted for age, gender, race, tobacco use, BMI, alcoholic drinks per week, education, physical activity, marital status, and antidepressant use. p-values for comparisons between adapted and maladapted categories. Data for insulin and leptin were log-transformed because values were not normally distributed. SE: standard error of the mean. A: Adapted. M: Maladapted. ln: natural logarithm. BMI: body mass index (kg/m^2).

Table 2.6. Metabolic Measures by Shiftwork Adaptation Group, BCOPS Study, 2023 (N=120)[a]

Metabolic Measure	Police Specific Model				
	Adapted (n=103)		Maladapted (n=17)		p-value
	Mean	SE	Mean	SE	A vs. M
Alanine Transaminase (U/L)	3.1	0.1	3.0	0.2	0.81
Aspartate Aminotransferase (U/L)	23.8	2.5	21.8	3.2	0.45
Adiponectin ln(ng/ml)	10	0.3	9.9	0.3	0.78
Total Cholesterol (mg/dL)	181	9.9	194	12.4	0.22
Cholesterol : HDL Ratio	3.6	0.3	4.3	0.3	**0.01**
Estimated Average Glucose (mg/dL)	104	4	104	5	0.88
Glomerular Filtration Rate (mL/min per 1.73 m^2)	4.1	0.003	4.1	0.002	0.94
Glucose (mg/dL)	91.2	3.9	93.9	4.8	0.51
Homocysteine ln(umol/L)	2.2	0.1	2.3	0.1	0.15
HbA1C (%)	5.3	0.1	5.2	0.2	0.88
HDL Cholesterol (mg/dL)	53.1	3.4	47.7	4.2	0.13
LDL Cholesterol (mg/dL)	109.1	8.5	121.2	10.6	0.18
Triglyceride (mg/dL)	93	16	124	20	0.07
Metabolic Syndrome Components	1.5	0.3	2.0	0.3	0.07
Metabolic Syndrome Severity Score	-0.3	0.2	0.2	0.2	**0.01**
Metabolic Measure	**General Symptom Model**				
	Adapted (n=110)		Maladapted (n=10)		p-value
	Mean	SE	Mean	SE	A vs. M
Alanine Transaminase (U/L)	3.0	0.1	3.0	0.2	0.98
Aspartate Aminotransferase (U/L)	23.4	2.5	21.7	4.0	0.60
Adiponectin ln(ng/ml)	10.0	0.3	9.4	0.4	0.07
Total Cholesterol (mg/dL)	185	9.7	175	15.9	0.46
Cholesterol : HDL Ratio	3.7	0.3	3.9	0.5	0.74
Estimated Average Glucose (mg/dL)	104	3.5	104.1	5.8	0.98
Glomerular Filtration Rate (mL/min per 1.73 m^2)	4.1	0	4.1	0	0.07
Glucose (mg/dL)	91.5	3.7	96.5	6.1	0.34
Homocysteine ln(umol/dL)	2.2	0.1	2.3	0.1	0.27
HbA1C (%)	5.3	0.1	5.3	0.2	0.98
HDL Cholesterol (mg/dL)	52.1	3.3	47.9	5.4	0.37
LDL Cholesterol (mg/dL)	112.4	8.4	106.1	13.7	0.59
Triglyceride (mg/dL)	100.1	16	103.7	26.2	0.87
Metabolic Syndrome Components	1.6	0.3	1.6	0.4	0.94
Metabolic Syndrome Severity Score	-0.2	0.2	0	0.3	0.33

[a] Least squares mean ± standard error of the mean. Models adjusted for age, gender, race, tobacco use, BMI, alcoholic drinks per week, education, physical activity, marital status, and antidepressant use. SE: standard error of the mean A: Adapted. M: Maladapted. ln: natural logarithm. BMI: body mass index (kg/m^2). Criteria for metabolic syndrome was defined based on the National Cholesterol Education Program Adult Treatment Panel guidelines (National Cholesterol Education Program Expert Panel on Detection and Cholesterol 2002).

Table 2.7. Heart Rate Variability/Autonomic Measures by Shiftwork Adaptation Group, BCOPS Study, 2023 (N=120)[a]

Heart Rate Variability Measures	Police Specific Model				
	Adapted (n=103)		Maladapted (n=17)		p-value
	Mean	SE	Mean	SE	A vs. M
SDNN (ms)	0.05	0.01	0.05	0.01	0.56
RMSSD (ms)	0.04	0.01	0.05	0.02	0.63
High Frequency (Burg) ln(ms^2/Hz)	5.1	0.4	5.0	0.5	0.85
Low Frequency (Burg) ln(ms^2/Hz)	5.2	0.4	5.3	0.5	0.89
High Frequency (Welch) (ms^2/Hz)	658	502	704	596.4	0.92
Low Frequency (Welch) (ms^2/Hz)	514.1	384.3	585	456.5	0.85

Heart Rate Variability Measures	General Symptom Model				
	Adapted (n=110)		Maladapted (n=10)		p-value
	Mean	SE	Mean	SE	A vs. M
SDNN (ms)	0.05	0.01	0.06	0.01	0.44
RMSSD (ms)	0.04	0.01	0.05	0.02	0.46
High Frequency (Burg) ln(ms^2/Hz)	5.1	0.4	5.1	0.6	0.98
Low Frequency (Burg) ln(ms^2/Hz)	5.2	0.4	5.3	0.5	0.89
High Frequency (Welch) (ms^2/Hz)	652.6	480	1123.5	712	0.39
Low Frequency (Welch) (ms^2/Hz)	523.7	368.9	788.7	547.2	0.53

[a]Least squares mean ± standard error of the mean (SE). Models adjusted for age, gender, race, tobacco use, BMI, alcoholic drinks per week, education, physical activity, marital status, and antidepressant use.
ln: natural log. HF-HRV: high frequency heart rate variability (0.15-0.40 Hz). LF-HRV: low frequency heart rate variability (0.04-0.15 Hz). SDNN: standard deviation of N-N intervals. RMSSD: root mean square of successive differences. BMI: body mass index (kg/m^2). ms: milliseconds. Hz: hertz.

Table 2.8. Global DNA Methylation by Shiftwork Adaptation Group, BCOPS Study, 2023 (N=120)[a]

	Police Specific Model				
	Adapted (n=103)		Maladapted (n=17)		p-value
	Mean	SE	Mean	SE	A vs. M
Mean LINE-1 Methylation	77.2	0.7	77.2	0.5	0.93

	General Symptom Model				
	Adapted (n=110)		Maladapted (n=10)		p-value
	Mean	SE	Mean	SE	A vs. M
Mean LINE-1 Methylation	77.0	0.8	77.2	0.5	0.76

[a] Least squares mean ± standard error of the mean. Models adjusted for age, gender, race, tobacco use, BMI, alcoholic drinks per week, education, physical activity, marital status, and antidepressant use. SE: standard error of the mean.

APPENDIX - Aim 2

Table A.2.1 Description of Latent Class Analysis Indicator Variables	
Indicator Variable	**Variable Description**
Pittsburgh Sleep Quality Index	Sleep disturbance, quality, duration, latency, medication usage, habitual sleep efficiency, and daytime dysfunction are components of the Pittsburgh Sleep Quality Index (PSQI). This 19 item self-administered questionnaire evaluates sleep quality over a one-month period [3]. Individual components are scored on a 4-point Likert scale ranging from 0-3. For this analysis, individual components were dichotomized using a cut-off value of ≥2. Scores ≥ 2 indicate poor sleep.
Spielberger Police Stress Survey	Physical and psychological threats (24 items), administrative and organizational pressure (23 items), and lack of support (13 items) are subscales of the Spielberger Police Stress Survey (SPPS) and consists of 60 items that assess acute and chronic stress in police officers [34]. Scores across the 60-items were summed to get a total stress rating. For this analysis, participants in the highest quartile are considered to have high stress for the total stress rating and each component.
Vital Exhaustion	Fatigue was measured using vital exhaustion (VE), which measures feelings of excessive fatigue and lack of energy; increasing irritability; and feelings of demoralization. Individual components include: 1) Do you feel more listless than before joining law enforcement?; 2) Do you sometimes feel that your body is like a battery that is losing its power?; 3) Do you feel dejected?; 4) Do you frequently experience a sense of exhaustion at work?; 5) Do you often feel tired?; 6) Do you often have trouble falling asleep?; 7) Do you repeatedly wake up in the middle of the night?; 8) Do you feel weak all over?; 9) Do little things irritate you more than before you joined law enforcement?; 10) Do you ever wake up with feelings of exhaustion and fatigue? [6]. A yes response indicates a poor or maladaptive response. For this analysis, scores across the 10-items were summed to get a total fatigue rating. Participants in the highest quartile are considered to have high fatigue.
Social Support	Social support (SS) was measured using the Social Provisions Scale, which consists of 22 items that were developed to assess six provisions of social relationships [35]. For this analysis, participants below the 75% percentile cut-off were considered to have low social support.
Perceived Stress	Perceived stress is measured using the perceived stress scale (PSS), which is a 10-item scale that measures the frequency of stressful events and experiences during the previous [7]. Perceived stress is measured on a 5-point Likert scale ranging from 0-4. For this analysis, participants in the highest quartile were considered to have high perceived stress.
Depression	Depression was measured using the Center for Epidemiologic Studies Depression Scale (CESD) [8]. Participants with a score ≥16 are considered to have depression.

Table A.2.2 Fit Statistics for Latent Class Models

	Police Specific Model							General Symptom Model						
Number of Classes	Residual df	AIC	BIC	G^2	Entropy	χ^2-GOF	%Solution	Residual df	AIC	BIC	G^2	Entropy	χ^2-GOF	%Solution
2	20	650.53	681.19	24.53	0.8	22.92	60.2	6	391.3	416.38	3.43	0.63	2.62	100.0
3	14	641.63	689.02	3.64	0.75	2.74	99.8	1	398.6	437.63	0.74	-0.02	0.47	79.2
4	8	651.47	715.59	1.47	0.88	0.88	46.0	-4	407.86	460.83	0	0.72	0	19.8
5	2	662.38	743.22	0.38	0.73	0.73	100.0	-9	417.86	484.76	0	0.41	0	47.2

Abbreviations: df = degrees of freedom; AIC = Akaike Information Criterion; BIC = Bayesian Information Criterion; G^2 = Likelihood-ratio chi-square statistic; χ^2-GOF = Chi-Square Goodness of Fit Test; %Solution – Percentage of seeds associated with best fitted model.

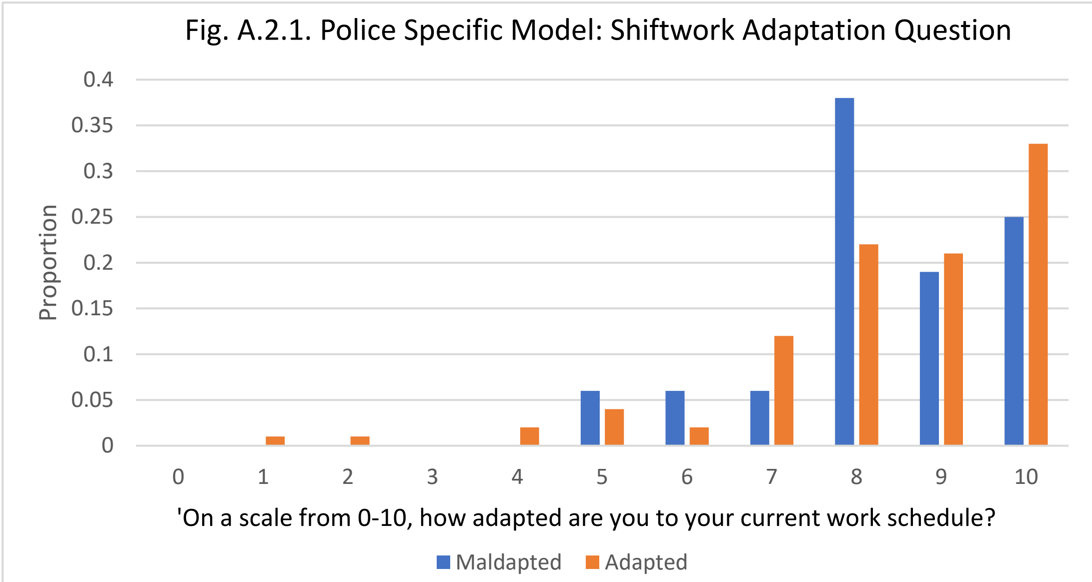

Figure A.2.1. A rating of 0 = not well adapted; 10 = very well adapted. BCOPS cohort (Buffalo, NY, USA).

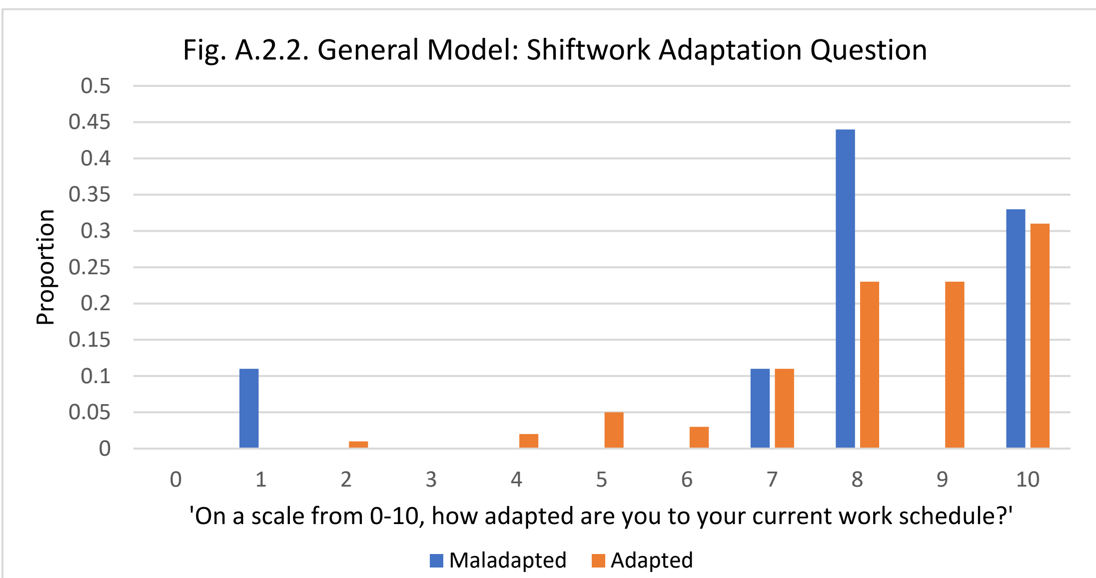

Figure A.2.2. A rating of 0 = not well adapted; 10 = very well adapted. BCOPS cohort (Buffalo, NY, USA).

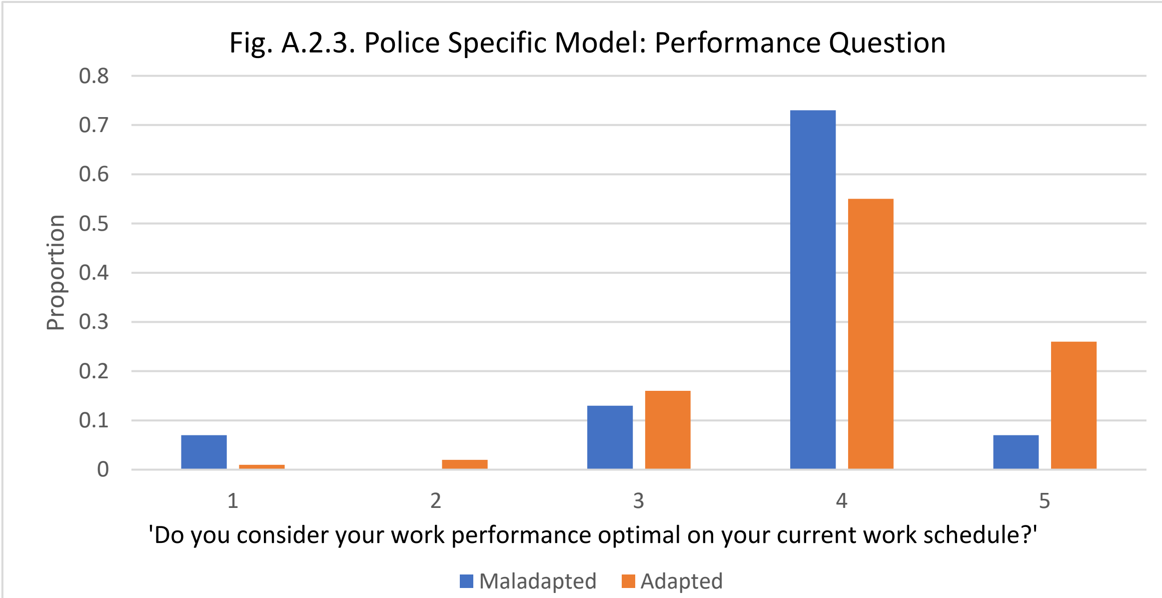

Figure A.2.3. A rating of 1 = strongly disagree; 5 = strongly agree. BCOPS cohort (Buffalo, NY, USA).

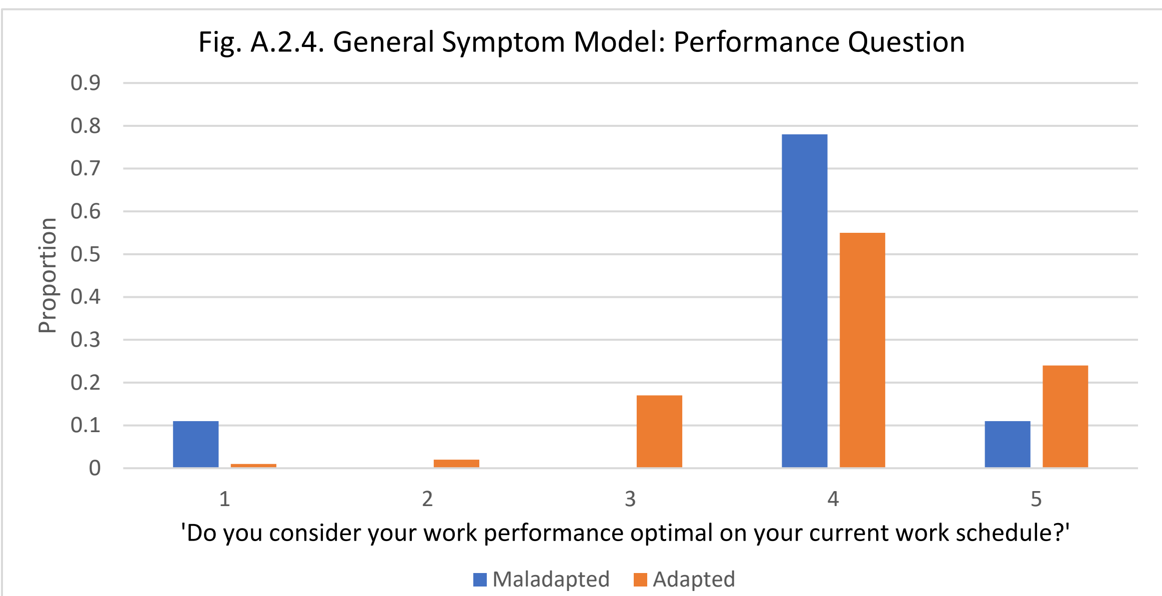

Figure A.2.4. A rating of 1 = strongly disagree; 5 = strongly agree. BCOPS cohort (Buffalo, NY, USA).

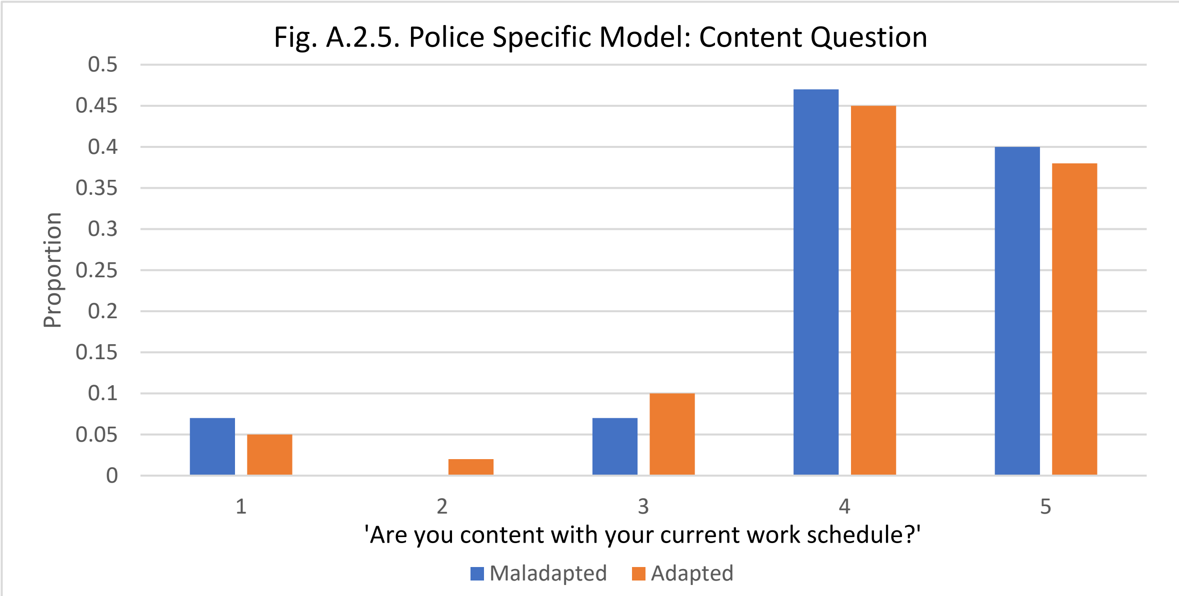

Figure A.2.5. Rating of 1 = strongly disagree; 5 = strongly agree. BCOPS cohort (Buffalo, NY, USA).

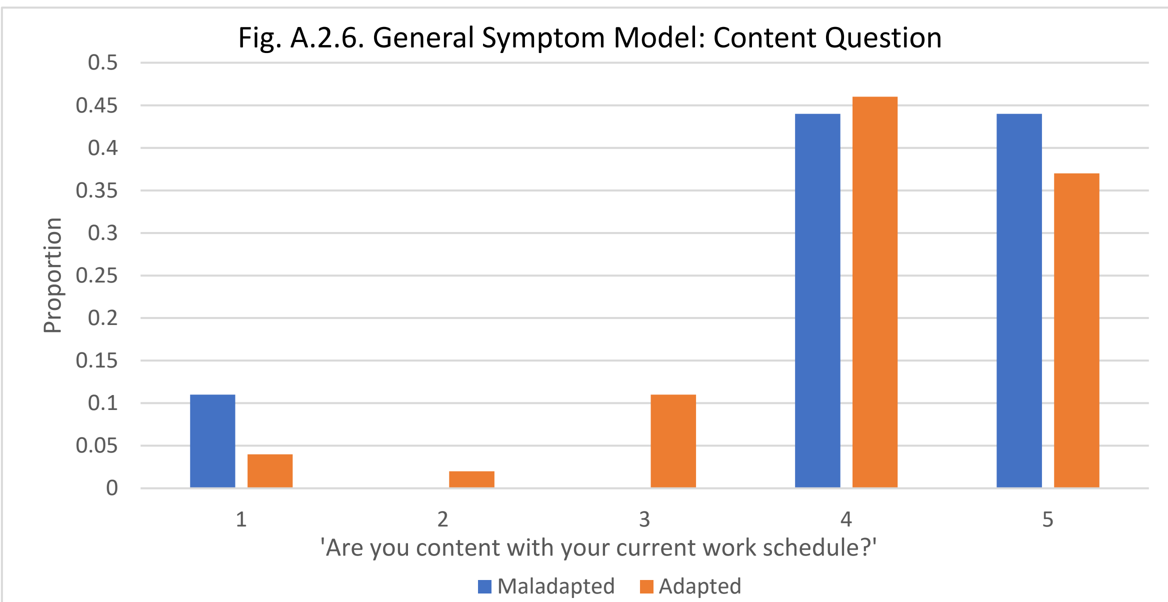

Figure A.2.6. Rating of 1 = strongly disagree; 5 = strongly agree. BCOPS cohort (Buffalo, NY, USA).

AIM 3 - *Characterize trajectories of adaptation/maladaptation to atypical work hours among police officers over time, examine changes in health indicators that are associated with different patterns of adaptation/maladaptation, and identify work-related adaptation strategies that are associated with beneficial or detrimental changes in the health indicators*.

Aim 3 Methods

Methods describing the questionnaires, work factor variables, and biomarkers are identical to those described for Aim 1. Statistical analyses to address Aim 3 used exploratory latent transition analyses (LTA) to prospectively model trajectories of symptoms associated with adaptation or maladaptation to atypical work hours among police officers in the BCOPS study. Data collection for this analysis occurred during three waves of clinical examinations among study participants enrolled over a median of ~12 years of follow-up (see Figure 1). Symptom indicator variables that were used to identify distinct LTA groups of adaptation/maladaptation were acquired from validated instruments characterizing: depression, anxiety, police stress, perceived stress, social support, vital exhaustion, and sleep quality. To identify latent classes, response scores for these measures were first divided into quartiles, and then dichotomized in a manner that assigned the most severe or worst-case symptom to those in the appropriate quartile. For example, assignment of '1' for social support indicated the lowest quartile of social support, whereas a '1' for perceived stress corresponded to the upper quartile of that score. Data on vital exhaustion was only available for the first two exam visits. Analyses were performed using the Mplus statistical software package (Version 8.9).

Initially, latent class analysis (LCA) was used to determine the number of classes that best fit the data at each study visit. Likelihood ratio tests were then performed in an LTA that examined measurement invariance and transition invariance to identify the best-fitting model separating participants into distinct groups based on their symptom trajectories over time. From this model, class membership was estimated for each participant at each time point along with conditional probabilities of having maladaptation symptoms given their class membership at each exam. A plot of the conditional probabilities for the indicator symptoms within each latent class over the entire study period was then produced, and a transition matrix was tabulated to examine the probability of changing class membership over time.

Class membership among groups with different patterns of adaptation/maladaptation symptoms over all three exams were evaluated to characterize transitions among study participants during the follow-up period (e.g., always adapted, always maladapted, changing from adapted to maladapted, changing from maladapted to adapted, or other more complex transition patterns). Characteristics of the participants in each of these groups were initially evaluated using descriptive statistics. Separate longitudinal logistic regression models were then used to univariately identify sociodemographic, work related, lifestyle, behavioral factors, or personality traits associated with persistent symptoms of adaptation, semi-maladaptation and maladaptation over time (see results section). For each factor, an interaction term with time (exam visit) was introduced into the model, and if the factor by time interaction term was statistically significant ($p<0.05$), odds ratios for that factor were tabulated separately for each study visit. These analyses identified factors associated with the odds of being in a persistently maladapted or semi-maladapted group relative to those who were always adapted, and were performed using the R 4.3.2 statistical software package.

Predicted group membership was then used as an independent variable to examine the role of adaptation/maladaptation patterns on biomarkers measured during the study period. Mixed effects longitudinal models were used to evaluate each biomarker after adjusting for *a priori* covariates. Separate models were fit for each biomarker with adjustment for the effects of: age, sex, race, education, marital status, police rank, and chronotype (morning, neutral, or evening based on each person's preferred sleep and wake times). An autoregressive correlation structure of order 1 (AR[1]) was assumed for repeated measurements within the dataset. For each model, type III tests were used to assess the statistical significance of the adaptation/maladaptation latent variable. These analyses were performed in SAS 9.4 with a nominal type I error rate of $\alpha=0.05$. One set of analyses was conducted using predicted class membership (Adapted, Semi-Maladapted, Maladapted) at each exam as the independent variable. Adjusted (least squares or LS) means of each continuous biomarker were estimated at each time point, and post-hoc statistical contrasts were performed using those classified as Adapted as the referent. Results were reported as the difference between the referent and each maladaptation group, and the statistical significance of differences between the LS means was tested using a t-statistic under the null hypothesis that the difference in LS means at each exam was zero.

For categorical biomarkers, odds ratios with 95% confidence intervals (CIs) were calculated at each study visit to assess the role of Maladaptation or Semi-Maladaptation among participants with an outcome exceeding its criterion (cut point) value. Metabolic syndrome (MetS) variables included a determination of whether a given participant met criteria for a MetS diagnosis based on consensus guidelines,[15] as well as the sum of the individual MetS criterion values that were exceeded, and the MetS severity score. Participants were classified as having MetS if they had at least three of the following criteria: waist circumference >102 cm for men and >88 cm for women; triglycerides ≥150 mg/dl, HDL cholesterol <40 mg/dl for men and <50 mg/dl for women; blood pressure ≥130/85 mmHg; or serum glucose ≥110 mg/dl. Categorical biomarkers that were analyzed included: a designation of metabolic syndrome (y/n), whether a given MetS criterion had been met (based cut points for waist circumference, triglycerides, HDL cholesterol, blood pressure, serum glucose), and elevated C-reactive protein (≥3 mg/L). These data were evaluated using multiple logistic regression with odds ratios and 95% confidence intervals (CIs) calculated at each study visit among participants grouped by adaptation/maladaptation categories of interest as the independent variable, and those who were Adapted as the referent.

In another set of biomarker analyses, the independent variable of interest was the LTA-assigned adaptation/maladaptation pattern summarized over all exams during the study period, rather than at each exam visit (i.e., Always Adapted, Always Maladapted, Always Semi-Maladapted, Adapted to Maladapted, Maladapted to Adapted, and Other). For continuous biomarkers, effect estimates were reported for adaptation/maladaptation patterns that were statistically significant using Always Adapted as the referent. For categorical biomarkers, an odds ratio with corresponding 95% CI was reported for each statistically significant adaptation transition pattern relative to the Always Adapted group.

Outcome Aim 3

For all three exam visits, the Bootstrap LRT for 4 versus 5 classes was not statistically significant. A transition model that was measurement invariant over time was considered to be more compatible with the overall analysis goals. Therefore, a 3-class LTA model was chosen as the most parsimonious approach to investigating longitudinal adaptation/maladaptation patterns among BCOPS participants (Table 3.1). Results for statistical tests of measurement invariance and transition invariance in the 3-class LTA model are presented in Table 3.2. The test for measurement invariance was statistically significant, although the fit statistics between the two models were very similar. For transition invariance, the LR test was not statistically significant, and the fit statistics indicated that a transition invariant model was preferred. Therefore, a measurement invariant LTA model with a single transition matrix was selected for further analysis (Table 3.2).

Figure 3.1 summarizes final LTA model results with class membership and item response probabilities for poor symptoms (maladaptation) among the symptom indicator variables. The model identified one group with consistent maladaptation symptoms and another without symptoms, consistent with an adapted phenotype. Interestingly, a third intermediate group was also identified (semi-maladapted) with elevated probabilities for poor sleep quality, stress, and vital exhaustion, but low probabilities for depression and anxiety.

The estimated probability of remaining in the same group was 0.787, 0.489, and 0.595 for the Adapted, Semi-Maladapted, and Maladapted groups, respectively (i.e., approximately 79%, 49%, and 60% of these group members remained in their original group during the study period, Table 3.3). Notably, the model results suggest that few participants transitioned into the Maladapted class (note the low probabilities in the last column of Table 3.3 for the Adapted and Semi-Maladapted groups). In addition, 45% of Semi-Maladapted and 40% of Maladapted participants were predicted to transition into the Always Adapted group (see Table 3.3, first column). Finally, the steady state solution for the transition matrix predicted that only ~6% of Maladapted personnel would remain in the Maladapted class (Table 3.3).

Descriptive statistics for the sociodemographic, occupational, lifestyle, behavioral, and personality characteristics were associated with each pattern of adaptation/maladaptation over the course of the study. includes all participants includes only participants who were measured at all three exams. Those in the Always Adapted and Maladapted to Adapted groups had relatively high rates of missing data, particularly at Exam 3, and results presented in Table 3.4b avoid this issue by presenting results only among those with complete data. Descriptive statistics for each LTA group stratified by study visit are presented using data available at the end of the study (see Appendix Aim 3, Table A.3.1).

The Always Adapted group had the lowest proportion of women (0%-15%), and the greatest proportions of women were present in the Always Maladapted (36%) and Adapted to Maladapted (33%-40%) groups relative to the other groups (Tables 3.4a and 3.4b). Most of those in the Always Adapted group (92%) had high physical activity relative to the other groups (61%-69%, Table 3.4b). Participants in the Always Adapted and Maladapted to Adapted groups tended to be older (55±8 and 58±9 years, respectively) and were more likely to have ≥20 years of police work experience (82% and 83%, respectively) relative to other groups (47-51 years, 35%-75%, Table 3.4b).

A majority of those in the Always Adapted group were in the low tertile of shift changes and those in the Maladapted to Adapted group were more likely to work day shifts (74%) and had fewer shift changes (87%) compared to other groups. Alternatively, those in the Always Maladapted, Always Semi-Maladapted, and Adapted to Maladapted groups were most likely to be in the upper tertile of shift changes. Personnel in these groups also tended to have high proportions of evening or night shift work and overtime hours relative to the other groups (Tables 3.4a and 3.4b). A greater proportion of those in the Always Maladapted group reported using antidepressants (14%) relative to those in other groups (0-8%, Tables 3.4a and 3.4b).

Results of longitudinal logistic regression models examining sociodemographics, occupational factors, lifestyles, behaviors, and personality traits associated with those in the Always Maladapted and Always Semi-Maladapted groups combined are presented in Table 3.5. After adjusting for covariates, those with persistent maladaptation or semi-maladaptation were slightly more likely to be older than those who were always adapted (OR: 1.04, CI: 1.03-1.06). They were 2.23 times more likely to be at a rank of detective or executive, they took fewer sick days during the study period (OR: 0.80, CI: 0.66-0.96), and they were 2.93 times more likely to have ≥20 years of police service at Exam 3 relative to the adapted group. Participants with persistent maladaptation or semi-maladaptation were also more likely to have more hardiness and familial commitment or control only at Exam 2 and not other study visits (Table 3.5).

Differences in adjusted (LS) mean cardiometabolic, endocrine, neurologic (HRV), inflammatory/immune, and epigenetic (LINE-1 DNA methylation) biomarker levels were compared among those with an Always Maladapted or Always Semi-Maladapted symptom pattern over time relative to those in the Always Adapted (referent) group. Values reported in Table 3.6 are the LS mean biomarker level after subtracting the value of the referent LS mean; positive differences represent an increased biomarker level in the Maladapted/Semi-Maladapted group, and negative differences reflect a decrease in the biomarker of interest (bold font represents a statistically significant biomarker change in the hypothesized direction). Total and LDL cholesterol were both elevated in the Semi-Maladapted group at Exam 1 (both $p<0.01$) but not at any other study visits Table 3.6. Similarly, estimated average blood glucose and glycated hemoglobin (HbA1C) were elevated in the Maladapted group at Exam 2 (both $p<0.01$) but not at other study visits. At Exam 2, decreases in measures of parasympathetic autonomic nervous system activity (RMSSD, HF HRV) were observed in the Maladapted group relative to the Adapted group (both $p<0.01$). At Exam 3, those in the Maladapted group had elevated LF-HRV values compared to referents ($p<0.01$). In general, reduced HRV values reflect poor health status, although LF-HRV measures can be state dependent. LF-HRV reflects both sympathetic and parasympathetic activity and an increase could be indicative of increased sympathetic activity related acute stress. Also at Exam 3, those in the Maladapted group had elevated levels of the inflammation biomarker, CRP, relative to the referent group ($p<0.05$, Table 3.6). Several biomarkers differed in a manner that was not hypothesized, including elevated HDL cholesterol at Exam 1 (Semi-Maladapted group), decreases in homocysteine and adiponectin, and increases in RMSSD, SDNN, and HF-HRV at Exam 3 (Maladapted group, Table 3.6). When categorical biomarkers were examined at each study visit, there were no statistically significant increases in the odds of maladaptation or semi-maladaptation among participants with a biomarker outcome above criterion values (Table A.3.2, Appendix Aim 3).

Summarized results for statistically significant biomarker changes that were observed as a function of the combined adaptation/maladaptation pattern estimated for each participant over the entire study period (i.e., using groups classified as: Always Adapted, Always Maladapted, Always Semi-Maladapted, Adapted to Maladapted, Maladapted to Adapted, and Other rather than groups of Adapted, Semi-Maladapted, and Maladapted at each exam) are presented in Table 3.7. Values of the liver function enzyme, alanine aminotransferase (ALT, p=0.03) and thyroid stimulating hormone (TSH, p=0.008) were both elevated among those in the Always Maladapted group relative to the Always Adapted referents. Because the metabolic hormone, thyroxine, is subject to reciprocal inhibition under normal circumstances, elevated TSH levels are typically interpreted as a deficiency in this metabolic hormone, although in this analysis there was no corresponding reduction in the thyroxine precursor, triiodothyronine (T3). Total cholesterol was elevated among those in the Maladapted to Adapted transition group (p=0.04), and SDNN was reduced among those in the Other transition group (p=0.02, Table 3.7).

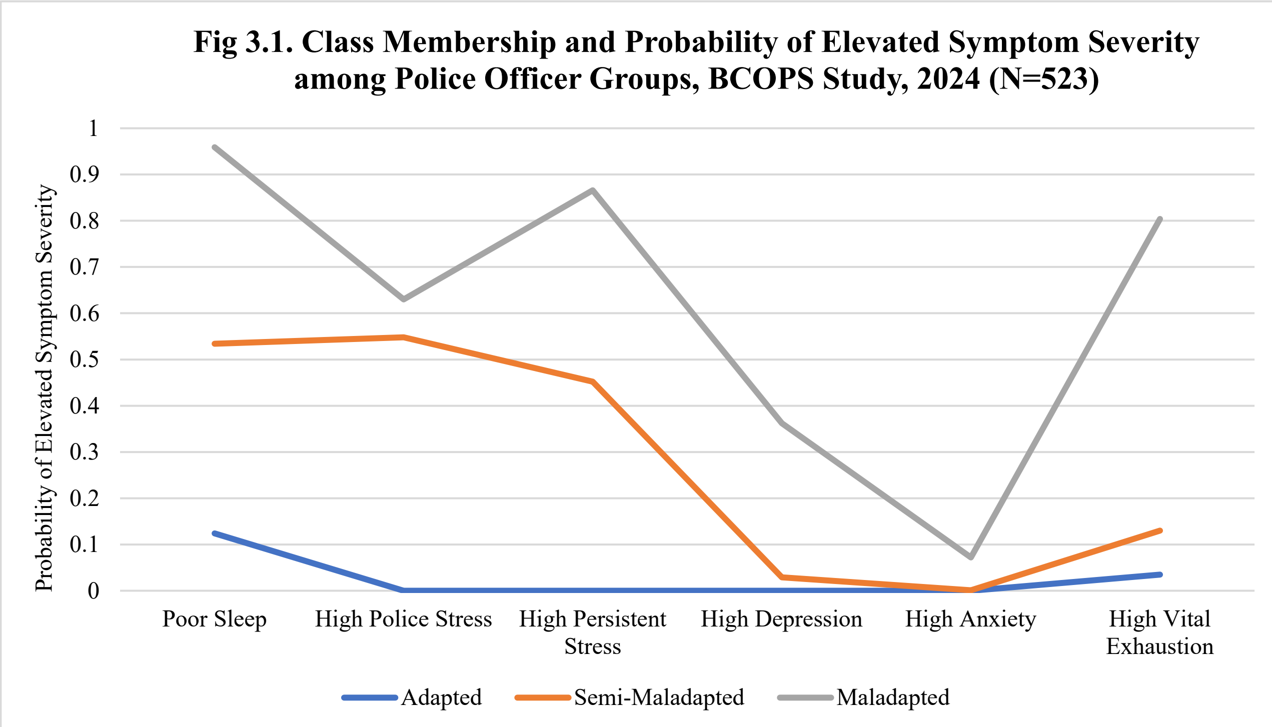

Figure 3.1. Results of latent transition analysis showing class membership and item-response probabilities (1=high or 100% probability of elevated symptom severity). Symptoms were evaluated for their contribution to shiftwork maladaptation in police officers (BCOPS study, Buffalo, NY, USA).

Table 3.1. Latent Class Analysis Model Fit Statistics by Study Visit, BCOPS Study, 2024

Number of Classes	G^2	AIC	BIC	ABIC	Entropy	DF
Exam 1						
2-Class	78.37	2792	**2847**	2806	**0.74**	50
3-Class	38.63	**2767**	**2851**	**2788**	0.62	43
4-Class	26.23	**2768**	2883	**2797**	0.68	36
5-Class	14.69	**2770**	2915	2807	0.69	29
Exam 2						
2-Class	72.11	2209	**2264**	2223	0.80	50
3-Class	24.33	**2172**	**2257**	**2194**	0.77	43
4-Class	9.98	**2172**	2287	**2201**	**0.93**	36
5-Class	7.40	2183	2328	2220	0.95	29
Exam 3						
2-Class	25.32	**1640**	**1687**	**1652**	0.76	20
3-Class	7.65	**1635**	1707	**1653**	0.81	14
4-Class	1.18	**1640**	1738	1665	**0.88**	8
5-Class	0.00	1651	1775	1683	0.87	2

Bolded text indicates classes that are at most ten units away from the minimum statistic calculated, or have maximum entropy. LCA: Latent class analysis. G^2: LR Statistics. AIC: Akaike Information Criterion. BIC: Bayesian Information Criterion. ABIC: Sample size-adjusted BIC. DF: Degrees of freedom.

Table 3.2. Latent Transition Analysis: Model Fit Statistics of Measurement Invariance and Transition Invariance, BCOPS Study 2024

Measurement Invariance							
MI	**LL**	**BIC**	**ABIC**	**DF**	**Diff LL**	**Diff DF**	**p-Value**
Yes	-3192	6584	6483	32			
No	-3139	6686	6479	65	52.7	33	0.016
Transition Invariance Given MI							
TI	**LL**	**BIC**	**ABIC**	**DF**	**Diff LL**	**Diff DF**	**p-Value**
Yes	-3194	6551	6468	26			
No	-3192	6584	6483	32	1.9	6	0.933

LL: Log-Likelihood. BIC: Bayesian Information Criterion. ABIC: Sample size-adjusted BIC. DF: Degrees of Freedom. Diff LL: Difference in LL Statistics. Diff DF: Difference in DF.

Table 3.3. Transition Matrix Describing Probability of Changing Class Membership Over Time, BCOPS Cohort, 2024

Starting Class Membership	**Predicted Class Membership at End of Study**		
	Adapted	Semi-Maladapted	Maladapted
Adapted	0.787	0.202	0.011
Semi-Maladapted	0.451	0.489	0.060
Maladapted	0.404	0.001	0.595
Steady State Solution			
Class Membership Probability	0.675	0.267	0.058

Table 3.4a. Participant Characteristics by Symptom Adaptation Pattern, BCOPS Cohort, 2024 (N=523)

Characteristic[1]	Adapted to Maladapted (N=55)	Always Adapted[2] (N=80)	Always Maladapted (N=36)	Always Semi-Maladapted (N=54)	Maladapted to Adapted[2] (N=258)	Other (N=40)
SOCIODEMOGRAPHICS						
Age						
Mean (SD)	40 (9)	44 (12)	51 (8)	51 (6)	58 (9)	49 (7)
Median (Min, Max)	39 (21, 58)	42 (27, 75)	51 (34, 69)	51 (40, 69)	59 (43, 78)	49 (37, 68)
Missing	0 (0%)	52 (65%)	0 (0%)	0 (0%)	218 (85%)	13 (33%)
Race/Ethnicity						
European American	44 (80%)	23 (29%)	33 (92%)	41 (76%)	33 (13%)	21 (53%)
African American	8 (15%)	5 (6%)	3 (8%)	13 (24%)	7 (3%)	6 (15%)
Hispanic	3 (5%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Missing	0 (0%)	52 (65%)	0 (0%)	0 (0%)	218 (85%)	13 (33%)
Sex						
Female	18 (33%)	12 (15%)	13 (36%)	13 (24%)	69 (27%)	12 (30%)
Male	37 (67%)	68 (85%)	23 (64%)	41 (76%)	189 (73%)	28 (70%)
Marital Status						
Single	11 (20%)	5 (6%)	3 (8%)	6 (11%)	4 (2%)	3 (8%)
Married	39 (71%)	21 (26%)	23 (64%)	42 (78%)	25 (10%)	18 (45%)
Divorced	5 (9%)	2 (3%)	10 (28%)	6 (11%)	10 (4%)	6 (15%)
Missing	0 (0%)	52 (65%)	0 (0%)	0 (0%)	219 (85%)	13 (33%)
Education						

Table 3.4a. Participant Characteristics by Symptom Adaptation Pattern, BCOPS Cohort, 2024 (N=523)

Characteristic[1]	Adapted to Maladapted (N=55)	Always Adapted[2] (N=80)	Always Maladapted (N=36)	Always Semi-Maladapted (N=54)	Maladapted to Adapted[2] (N=258)	Other (N=40)
≤12 yrs	1 (2%)	2 (3%)	2 (6%)	2 (4%)	4 (2%)	0 (0%)
College <4 yrs	28 (51%)	16 (20%)	17 (47%)	29 (54%)	21 (8%)	11 (28%)
College ≥4 yrs	26 (47%)	10 (13%)	17 (47%)	23 (43%)	15 (6%)	16 (40%)
Missing	0 (0%)	52 (65%)	0 (0%)	0 (0%)	218 (85%)	13 (33%)
Military Service						
No	47 (86%)	21 (26%)	30 (83%)	48 (89%)	27 (11%)	22 (55%)
Yes	8 (15%)	7 (9%)	6 (17%)	6 (11%)	13 (5%)	5 (13%)
Missing	0 (0%)	52 (65%)	0 (0%)	0 (0%)	218 (85%)	13 (33%)
WORK FACTORS						
Years Served (<20 years)	44 (80%)	17 (21%)	9 (25%)	18 (33%)	7 (3%)	13 (33%)
Years Served (≥20 years)	11 (20%)	11 (14%)	27 (75%)	36 (67%)	33 (13%)	14 (35%)
Missing	0 (0%)	52 (65%)	0 (0%)	0 (0%)	218 (85%)	13 (33%)
Police Rank						
Police Officer	34 (62%)	16 (20%)	14 (39%)	28 (52%)	15 (6%)	12 (30%)
Sgt/Lt/Capt	12 (22%)	8 (10%)	10 (2%)	10 (19%)	11 (4%)	9 (23%)
Detective	8 (15%)	4 (5%)	10 (28%)	14 (26%)	11 (4%)	6 (15%)
Executive	1 (2%)	0 (0%)	0 (0%)	2 (4%)	2 (1%)	0 (0%)
Missing	0 (0%)	52 (65%)	2 (6%)	0 (0%)	219 (85%)	13 (33%)

Table 3.4a. Participant Characteristics by Symptom Adaptation Pattern, BCOPS Cohort, 2024 (N=523)

Characteristic[1]	Adapted to Maladapted (N=55)	Always Adapted[2] (N=80)	Always Maladapted (N=36)	Always Semi-Maladapted (N=54)	Maladapted to Adapted[2] (N=258)	Other (N=40)
WORK FACTORS						
Dominant Work Shift						
Days	22 (40%)	9 (11%)	13 (36%)	28 (52%)	30 (12%)	10 (25%)
Evenings	19 (35%)	11 (14%)	17 (47%)	20 (37%)	3 (1%)	11 (28%)
Nights	14 (26%)	7 (9%)	6 (17%)	6 (11%)	7 (3%)	6 (15%)
Evenings or Nights	33 (61%)	18 (23%)	23 (64%)	26 (48%)	10 (4%)	17 (43%)
Missing	0 (0%)	53 (66%)	0 (0%)	0 (0%)	218 (85%)	13 (33%)
Shift Changes						
Low Tertile	27 (49%)	59 (74%)	6 (17%)	11 (20%)	224 (87%)	17 (43%)
Middle Tertile	18 (33%)	5 (6%)	9 (25%)	19 (35%)	11 (4%)	16 (40%)
Upper Tertile	10 (18%)	5 (6%)	21 (58%)	24 (44%)	14 (5%)	7 (18%)
Missing	0 (0%)	11 (14%)	0 (0%)	0 (0%)	9 (4%)	0 (0%)
Overtime Hours						
Low Tertile	23 (42%)	49 (61%)	11 (31%)	18 (33%)	218 (85%)	24 (60%)
Middle Tertile	18 (33%)	14 (18%)	10 (28%)	16 (30%)	14 (5%)	7 (18%)
Upper Tertile	14 (26%)	6 (8%)	15 (42%)	20 (37%)	17 (7%)	9 (23%)
Missing	0 (0%)	11 (14%)	0 (0%)	0 (0%)	9 (4%)	0 (0%)

Table 3.4a. Participant Characteristics by Symptom Adaptation Pattern, BCOPS Cohort, 2024 (N=523)

Characteristic[1]	Adapted to Maladapted (N=55)	Always Adapted[2] (N=80)	Always Maladapted (N=36)	Always Semi-Maladapted (N=54)	Maladapted to Adapted[2] (N=258)	Other (N=40)
Second Jobs						
None	34 (62%)	18 (23%)	24 (67%)	36 (67%)	23 (9%)	14 (35%)
<1 Shift per week,	8 (15%)	2 (3%)	1 (3%)	4 (7%)	1 (0.4%)	8 (20%)
≥1 Shift per week	13 (24%)	8 (10%)	11 (31%)	14 (26%)	16 (6%)	5 (13%)
Missing	0 (0%)	52 (65%)	0 (0%)	0 (0%)	218 (85%)	13 (33%)
Occupational Stress Score						
Low	15 (27%)	9 (11%)	4 (11%)	10 (19%)	6 (2%)	6 (15%)
Medium	38 (69%)	17 (21%)	26 (72%)	34 (63%)	23 (9%)	18 (45%)
High	2 (4%)	1 (1%)	6 (17%)	10 (19%)	11 (4%)	3 (8%)
Missing	0 (0%)	53 (66%)	0 (0%)	0 (0%)	218 (85%)	13 (33%)
No. of Sick Days						
Mean (SD)	1.0 (0.8)	0.7 (0.7)	0.6 (0.8)	0.9 (0.8)	0.7 (0.8)	0.8 (0.9)
Median (Min, Max)	1 (0, 3)	1 (0, 2)	0.5 (0, 3)	1 (0, 3)	0.5 (0, 3)	0 (0, 3)
Missing	0 (0%)	52 (65%)	0 (0%)	0 (0%)	218 (85%)	13 (33%)
LIFESTYLE & BEHAVIOR						
Alcoholic Beverages Per Week						
Quartiles 1-3	41 (75%)	24 (30%)	28 (78%)	35 (65%)	31 (12%)	20 (50%)
Quartile 4	12 (22%)	4 (5%)	8 (22%)	16 (30%)	9 (4%)	6 (15%)
Missing	2 (4%)	52 (65%)	0 (0%)	3 (6%)	218 (85%)	14 (35%)

Table 3.4a. Participant Characteristics by Symptom Adaptation Pattern, BCOPS Cohort, 2024 (N=523)

Characteristic[1]	Adapted to Maladapted (N=55)	Always Adapted[2] (N=80)	Always Maladapted (N=36)	Always Semi-Maladapted (N=54)	Maladapted to Adapted[2] (N=258)	Other (N=40)
Weekly Servings of Fat						
Quartiles 1-3	46 (84%)	25 (31%)	30 (83%)	48 (89%)	39 (15%)	23 (58%)
Quartile 4	7 (13%)	3 (4%)	6 (17%)	5 (9%)	1 (0.4%)	3 (8%)
Missing	2 (4%)	52 (65%)	0 (0%)	1 (2%)	218 (85%)	14 (35%)
Weekly Servings of Vegetables						
Quartiles 1-3	42 (76%)	21 (26%)	29 (81%)	49 (91%)	36 (14%)	20 (50%)
Quartile 4	11 (20%)	7 (9%)	7 (19%)	4 (7%)	4 (2%)	6 (15%)
Missing	2 (4%)	52 (65%)	0 (0%)	1 (2%)	218 (85%)	14 (35%)
Weekly Servings of Fruit						
Quartiles 1-3	46 (84%)	22 (28%)	30 (83%)	47 (87%)	36 (14%)	20 (50%)
Quartile 4	8 (15%)	6 (8%)	6 (17%)	6 (11%)	4 (2%)	6 (15%)
Missing	1 (2%)	52 (65%)	0 (0%)	1 (2%)	218 (85%)	14 (35%)
Physical Activity Level						
Low	2 (4%)	1 (1%)	4 (11%)	5 (9%)	2 (1%)	5 (13%)
Mid	11 (20%)	8 (10%)	10 (28%)	22 (41%)	11 (4%)	5 (13%)
High	41 (75%)	19 (24%)	22 (61%)	27 (50%)	27 (11%)	17 (43%)
Missing	1 (2%)	52 (65%)	0 (0%)	0 (0%)	218 (85%)	13 (33%)

This resource was prepared by the author(s) using Federal funds provided by the U.S. Department of Justice. Opinions or points of view expressed are those of the author(s) and do not necessarily reflect the official position or policies of the U.S. Department of Justice.

Table 3.4a. Participant Characteristics by Symptom Adaptation Pattern, BCOPS Cohort, 2024 (N=523)

Characteristic[1]	Adapted to Maladapted (N=55)	Always Adapted[2] (N=80)	Always Maladapted (N=36)	Always Semi-Maladapted (N=54)	Maladapted to Adapted[2] (N=258)	Other (N=40)
Antidepressant Use						
No	52 (94%)	78 (98%)	31 (86%)	53 (98%)	250 (97%)	37 (92%)
Yes	3 (6%)	0 (0%)	5 (14%)	1 (2%)	3 (1%)	3 (8%)
Missing	0 (0%)	2 (2%)	0 (0%)	0 (0%)	5 (2%)	0 (0%)

1 - Data presented from the end of the study period at Exam 3. Column percentages within a given category may not total 100% due to rounding or missing data. 2 - Both the Always Adapted and Maladapted to Adapted groups have high rates of missingness at Exam 3 because people in these categories tended to only be measured at the first two exams. Table 3.4b presents descriptive characteristics of people measured at all three exams.

This resource was prepared by the author(s) using Federal funds provided by the U.S. Department of Justice. Opinions or points of view expressed are those of the author(s) and do not necessarily reflect the official position or policies of the U.S. Department of Justice.

Table 3.4b. COMPLETE CASES - Participant Characteristics by Symptom Adaptation Pattern, BCOPS Cohort, 2024 (N=176)

Characteristic[1]	Adapted to Maladapted (N=20)	Always Adapted (N=12)	Always Maladapted (N=36)	Always Semi-Maladapted (N=54)	Maladapted to Adapted (N=38)	Other (N=16)
SOCIODEMOGRAPHICS						
Age						
Mean (SD)	47 (7)	55 (8)	51 (8)	51 (6)	58 (9)	47 (5)
Median (Min, Max)	46 (33, 58)	53 (43, 75)	51 (34, 69)	51 (40, 69)	59 (43, 78)	48 (37, 60)
Race/Ethnicity						
White	15 (75%)	10 (83%)	33 (92%)	41 (76%)	32 (84%)	13 (81%)
African American	4 (20%)	2 (17%)	3 (8%)	13 (24%)	6 (16%)	3 (19%)
Hispanic	1 (5%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Sex						
Female	8 (40%)	0 (0%)	13 (36%)	13 (24%)	8 (21%)	5 (31%)
Male	12 (60%)	12 (100%)	23 (64%)	41 (76%)	30 (79%)	11 (69%)
Marital Status						
Single	2 (10%)	0 (0%)	3 (8%)	6 (11%)	4 (11%)	2 (13%)
Married	15 (75%)	10 (83%)	23 (64%)	42 (78%)	23 (61%)	11 (69%)
Divorced	3 (15%)	2 (17%)	10 (28%)	6 (11%)	10 (26%)	3 (19%)
Missing	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (3%)	0 (0%)
Education						
≤12 yrs	0 (0%)	2 (17%)	2 (6%)	2 (4%)	4 (11%)	0 (0%)
College < 4 yrs	11 (55%)	8 (67%)	17 (47%)	29 (54%)	19 (50%)	6 (38%)
College ≥4 yrs	9 (45%)	2 (17%)	17 (47%)	23 (43%)	15 (40%)	10 (63%)
Military Service						
No	17	7	30	48	25	14

Table 3.4b. COMPLETE CASES - Participant Characteristics by Symptom Adaptation Pattern, BCOPS Cohort, 2024 (N=176)

Characteristic[1]	Adapted to Maladapted (N=20)	Always Adapted (N=12)	Always Maladapted (N=36)	Always Semi-Maladapted (N=54)	Maladapted to Adapted (N=38)	Other (N=16)
	(85%)	(58%)	(83%)	(89%)	(66%)	(88%)
Yes	3 (15%)	5 (42%)	6 (17%)	6 (11%)	13 (34%)	2 (13%)
WORK FACTORS						
Years Served						
<20 Yrs	13 (65%)	2 (17%)	9 (25%)	18 (33%)	7 (18%)	9 (56%)
≥20 Yrs	7 (35%)	10 (83%)	27 (75%)	36 (67%)	31 (82%)	7 (44%)
Police Rank						
Police Officer	7 (35%)	5 (42%)	14 (39%)	28 (52%)	14 (37%)	7 (44%)
Sgt/Lieut/Capt	7 (35%)	5 (42%)	10 (28%)	10 (19%)	10 (26%)	5 (31%)
Detective	5 (25%)	2 (17%)	10 (28%)	14 (26%)	11 (29%)	4 (25%)
Executive	1 (5%)	0 (0%)	0 (0%)	2 (4%)	2 (5%)	0 (0%)
Missing	0 (0%)	0 (0%)	2 (6%)	0 (0%)	1 (3%)	0 (0%)
Dominant Work Shift						
Days	10 (50%)	4 (33%)	13 (36%)	28 (52%)	28 (74%)	5 (31%)
Evenings	4 (20%)	5 (42%)	17 (47%)	20 (37%)	3 (8%)	7 (44%)
Nights	6 (30%)	3 (25%)	6 (17%)	6 (11%)	7 (18%)	4 (25%)
Evenings or Nights	10 (50%)	8 (67%)	23 (64%)	26 (48%)	10 (26%)	11 (68%)
Shift Changes						
Low Tertile	3 (15%)	4 (33%)	6 (17%)	11 (20%)	15 (40%)	2 (13%)
Mid Tertile	9	4	9	19	9	9

Table 3.4b. COMPLETE CASES - Participant Characteristics by Symptom Adaptation Pattern, BCOPS Cohort, 2024 (N=176)

Characteristic[1]	Adapted to Maladapted (N=20)	Always Adapted (N=12)	Always Maladapted (N=36)	Always Semi-Maladapted (N=54)	Maladapted to Adapted (N=38)	Other (N=16)
	(45%)	(33%)	(25%)	(35%)	(24%)	(56%)
Upper Tertile	8 (40%)	4 (33%)	21 (58%)	24 (44%)	14 (37%)	5 (31%)
Overtime Hours						
Low Tertile	12 (60%)	2 (17%)	11 (31%)	18 (33%)	8 (21%)	6 (38%)
Mid Tertile	6 (30%)	7 (58%)	10 (28%)	16 (30%)	14 (37%)	5 (31%)
Upper Tertile	2 (10%)	3 (25%)	15 (42%)	20 (37%)	16 (42%)	5 (31%)
Second Jobs						
None	14 (70%)	7 (58%)	24 (67%)	36 (67%)	23 (61%)	10 (63%)
<1 Shift per week	3 (15%)	0 (0%)	1 (3%)	4 (7%)	1 (3%)	6 (38%)
≥1 Shift per week	3 (15%)	5 (42%)	11 (31%)	14 (26%)	14 (37%)	0 (0%)
Occupational Stress						
Low	4 (20%)	1 (8%)	4 (11%)	10 (19%)	6 (16%)	4 (25%)
Medium	15 (75%)	11 (92%)	26 (72%)	34 (63%)	22 (58%)	10 (63%)
High	1 (5%)	0 (0%)	6 (17%)	10 (19%)	10 (26%)	2 (13%)
No. of Sick Days						
Mean (SD)	0.9 (0.6)	0.5 (0.7)	0.6 (0.7)	0.9 (0.8)	0.7 (0.8)	0.9 (1.0)
Median (Min, Max)	1 (0, 2)	0 (0, 2)	0.5 (0, 3)	1 (0, 3)	0 (0, 3)	0.5 (0, 3)
LIFESTYLE & BEHAVIOR						
Alcoholic Beverages Per Week						
Quartiles 1-3	15 (75%)	11 (92%)	28 (78%)	35 (65%)	29 (76%)	12 (75%)

Table 3.4b. COMPLETE CASES - Participant Characteristics by Symptom Adaptation Pattern, BCOPS Cohort, 2024 (N=176)

Characteristic[1]	Adapted to Maladapted (N=20)	Always Adapted (N=12)	Always Maladapted (N=36)	Always Semi-Maladapted (N=54)	Maladapted to Adapted (N=38)	Other (N=16)
Quartile 4	4 (20%)	1 (8%)	8 (22%)	16 (30%)	9 (24%)	4 (25%)
Missing	1 (5%)	0 (0%)	0 (0%)	3 (6%)	0 (0%)	0 (0%)
Weekly Servings of Fat						
Quartiles 1-3	17 (85%)	12 (100%)	30 (83%)	48 (89%)	37 (97%)	13 (81%)
Quartile 4	2 (10%)	0 (0%)	6 (17%)	5 (9%)	1 (3%)	3 (19%)
Missing	1 (5%)	0 (0%)	0 (0%)	1 (2%)	0 (0%)	0 (0%)
Weekly Servings of Vegetables						
Quartiles 1-3	16 (80%)	10 (83%)	29 (81%)	49 (91%)	34 (90%)	13 (81%)
Quartile 4	3 (15%)	2 (17%)	7 (19%)	4 (7%)	4 (11%)	3 (19%)
Missing	1 (5%)	0 (0%)	0 (0%)	1 (2%)	0 (0%)	0 (0%)
Weekly Servings of Fruit						
Quartiles 1-3	18 (90%)	11 (92%)	30 (83%)	47 (87%)	34 (90%)	13 (81%)
Quartile 4	2 (10%)	1 (8%)	6 (17%)	6 (11%)	4 (11%)	3 (19%)
Missing	0 (0%)	0 (0%)	0 (0%)	1 (2%)	0 (0%)	0 (0%)
Physical Activity Level						
Low	2 (10%)	0 (0%)	4 (11%)	5 (9%)	2 (5%)	3 (19%)
Mid	4 (20%)	1 (8%)	10 (28%)	22 (41%)	11 (29%)	3 (19%)
High	13 (65%)	11 (92%)	22 (61%)	27 (50%)	25 (69%)	10 (63%)
Missing	1	0	0	0	0	0

Table 3.4b. COMPLETE CASES - Participant Characteristics by Symptom Adaptation Pattern, BCOPS Cohort, 2024 (N=176)

Characteristic[1]	Adapted to Maladapted (N=20)	Always Adapted (N=12)	Always Maladapted (N=36)	Always Semi-Maladapted (N=54)	Maladapted to Adapted (N=38)	Other (N=16)
	(5%)	(0%)	(0%)	(0%)	(0%)	(0%)
Antidepressant Use						
No	19 (95%)	12 (100%)	31 (86%)	53 (98%)	35 (92%)	14 (88%)
Yes	1 (5%)	0 (0%)	5 (14%)	1 (2%)	3 (8%)	2 (13%)

1 - Data presented from the end of the study period at Exam 3, includes only participants measured at all 3 study visits. Column percentages may not total 100% due to rounding.

Table 3.5. Participant Characteristics Associated with Maladaptation and Semi-Maladaptation, BCOPS Cohort, 2024

Variable	**Odds of Maladaptation & Semi-Maladaptation vs. Always Adapted**	
	Odds Ratio	**95% CI**
SOCIODEMOGRAPHICS		
Age	**1.044**	**(1.025, 1.062)**
Body Mass Index	1.017	(0.98, 1.055)
Obesity (Yes vs. No)	1.202	(0.848, 1.705)
Race (Black vs. White)	1.028	(0.668, 1.582)
Ethnicity (Hispanic vs. White)	1.973	(0.543, 7.174)
Sex (Male vs. Female)	1.261	(0.915, 1.738)
Marital Status (Married vs. Single)	1.092	(0.654, 1.822)
Marital Status (Divorced vs. Single)	0.812	(0.435, 1.518)
Education (college degree vs. no college degree)	0.721	(0.504, 1.031)
Military Service (Yes vs. No)	1.365	(0.906, 2.058)
WORK RELATED		
Years Served (≥20 years vs. <20 years)		
Exam 1	1.178	(0.723, 1.920)
Exam 2	1.802	(0.878, 3.697)
Exam 3	**2.929**	**(1.321, 6.496)**
Police Rank (≥Detective vs. <Detective)	**2.230**	**(1.436, 3.462)**
Dominant Work Shift (Nights/Evenings vs. Days)	0.747	(0.53, 1.054)
No. of Shift Changes	1.001	(0.999, 1.004)
No. of Shift Changes (>median vs. ≤median)	1.033	(0.732, 1.457)
Overtime Hours (>10 hours vs. ≤10 hours)	1.140	(0.771, 1.685)
Second Job (Yes vs. No)	0.969	(0.688, 1.365)
No. of Sick Days	**0.796**	**(0.664, 0.955)**
LIFESTYLE & BEHAVIOR		
Physical Activity (elevated vs. not elevated)	0.894	(0.633, 1.263)
Tobacco Use (Current vs. Never)	1.134	(0.737, 1.746)
Tobacco Use (Former vs. Never)	1.170	(0.779, 1.757)
Alcoholic Beverages per Week (Q4 vs. Q1-3)	0.858	(0.588, 1.252)
Servings of Fat per Week (Q4 vs. Q1-3)	1.002	(0.998, 1.005)
Servings of Vegetables per Week (Q4 vs. Q1-3)	0.982	(0.572, 1.687)
Servings of Fruit per Week (Q4 vs. Q1-3)	0.647	(0.394, 1.063)
Antidepressant Use (Yes vs. No)	0.941	(0.574, 1.542)
PERSONALITY TRAITS[1]		
Commitment		
Exam 1	0.937	(0.842, 1.042)
Exam 2	**1.200**	**(1.031, 1.396)**
Exam 3	1.047	(0.891, 1.230)
Challenge	1.031	(0.969, 1.096)
Control		
Exam 1	0.863	(0.769, 0.969)
Exam 2	**1.262**	**(1.067, 1.492)**
Exam 3	1.027	(0.859, 1.226)
Hardiness		
Exam 1	0.963	(0.919, 1.009)
Exam 2	**1.079**	**(1.011, 1.152)**
Exam 3	1.028	(0.959, 1.101)

Adjusted for age, sex, race, education, marital status, police rank, and chronotype. Variables with an odds ratio for each exam had a statistically significant interaction with study visit. [1] - commitment, challenge, control, and hardiness are subscales of the Dispositional Resilience Scale. Q4 - upper quartile. Q1-3 - quartiles 1-3 combined.

Table 3.6. Differences[1] in Adjusted Mean Biomarker Outcomes among Maladapted or Semi-Maladapted Officers versus the Always Adapted Group, by Study Visit, BCOPS Cohort, 2024

Biomarker	Exam 1		Exam 2		Exam 3	
	Maladapted	Semi-Maladapted	Maladapted	Semi-Maladapted	Maladapted	Semi-Maladapted
Cardiometabolic						
log(ALT)[2]	n/a	n/a	0.069	0.004	-0.140	-0.069
AST[2]	n/a	n/a	0.61	-0.02	-0.87	-0.37
log(Adiponectin)	0.002	0.094	0.016	0.056	0.396**	0.109
Total Cholesterol	2.97	**12.24****	1.76	-6.25	1.78	3.80
HDL Cholesterol	-0.23	2.56*	-1.00	-1.81	2.69	-1.38
Cholesterol:HDL Ratio	-0.04	-0.03	0.17	-0.11	-0.23	0.15
LDL Cholesterol	2.46	**10.15****	-0.57	-3.21	0.18	3.57
Glucose	-2.92	-0.89	3.38	0.08	-1.48	-0.14
Est. Ave. Glucose	-1.90	-0.40	**5.65****	0.12	-1.23	-0.61
Triglycerides	2.81	-2.59	21.29	-4.54	-7.89	7.39
HbA1c	-0.066	-0.014	**0.197****	0.004	-0.043	-0.021
log(GFR)	0.029	0.007	-0.001	0.001	0.005	0.002
log(Homocysteine)	0.015	0.010	0.002	0.018	-0.112*	-0.054
No. of Metabolic Syndrome criteria met	-0.001	-0.002	0.027	0.094	-0.046	0.038
Metabolic Syndrome Severity Score	0.001	0.031	0.105	0.042	-0.107	0.086
Endocrine						
TSH	-0.02	-0.03	-0.13	-0.13	0.15	-0.17
T3	-0.03	-0.05	-0.04	**-0.05***	0.07	0.01
log(Insulin)	0.19	0.07	-0.08	-0.05	0.16	0.09
log(Leptin)	0.01	0.13	0.08	0.06	0.09	0.14
Heart Rate Variability						
SDNN	-0.002	-0.002	-0.005	-0.004	0.013**	0.001
RMSSD	-0.002	-0.005	**-0.010***	-0.002	0.018**	0.002
log(HF-Burg)	0.09	-0.03	**-0.42***	-0.02	0.48*	0.12
log(LF-Burg)	-0.02	-0.05	-0.21	-0.09	0.30	0.10
HF-Welch	-66.34	-149.92	-94.67	-15.23	477.70**	152.12
LF-Welch	-79.63	-105.39	-83.67	-51.47	**343.87****	65.42
Inflammatory/Immune						
log(CRP)	0.19	0.14	0.04	-0.09	0.38	**0.33***
log(IL-6)	0.028	-0.056	0.061	0.007	-0.058	0.012
TNF-alpha	0.12	0.17	-0.30	-0.12	-0.43	0.67
WBC	0.063	-0.082	0.140	-0.008	0.127	0.258
ICAM-1	-8.14	0.12	9.08	-11.42	6.04	16.88
Fibrinogen	-4.50	-1.29	-8.94	-3.94	14.10	12.55
Mean LINE-1 Methylation						
Mean LINE-1	0.37	0.48	-0.10	-0.45	0.23	-0.05

[1] LS mean in Always Adapted (referent) group subtracted from LS mean in Always Maladapted or Always Semi-Maladapted group (bold value indicates statistically significant change in the hypothesized direction). Adjusted for: age, sex, race, education level, marital status, police rank, and chronotype. * p<0.05, ** p<0.01, ***p<0.001. [2] ALT and AST were only measured at Exams 2 and 3. ALT: alanine aminotransferase. AST: aspartate aminotransferase. HbA1c: hemoglobin A1C. GFR: glomerular filtration rate. LDL: low-density lipoprotein. HDL: high-density lipoprotein. T3: triiodothyronine. TSH: thyroid stimulating hormone. SDNN: standard deviation of normal-to-normal heart beat intervals. RMSSD: root mean square of successive RR intervals. HF: high frequency HRV. LF: low frequency HRV. TNF: Tumor necrosis factor. CRP: C-reactive protein. WBC: white blood cell count. ICAM-1: Intercellular adhesion molecule 1. MetS: Metabolic Syndrome. LINE: Long interspersed nuclear element.

Table 3.7. Adaptation Patterns Associated with Biomarker Changes in Police Officers, BCOPS Cohort, 2024

Continuous Outcome	Adaptation Pattern[1]	Effect Estimate	Std Error	DF	p-value
log(ALT)	Always Maladapted	0.217	0.097	322	0.026
TSH	Always Maladapted	4.990	1.862	419	0.008
Total Cholesterol	Maladapted to Adapted	11.187	5.454	468	0.041
SDNN	Other	-0.010	0.004	352	0.023
Categorical Outcome	**Adaptation Pattern**	**Odds Ratio**	**95% CI**	**DF**	**p-value**
CRP ≥3 (mg/L)	Always Maladapted	0.331	(0.117, 0.935)	471	0.037
Low HDL Cholesterol	Always Semi-Maladapted	0.440	(0.210, 0.923)	471	0.030

1 - Adaptation patterns included: Always Adapted (referent), Always semi-Maladapted, Always Maladapted, changing from Always Adapted to semi- or fully Maladapted, changing from semi- or fully Maladapted to Always Adapted, and Other (changing more than once in either direction during the course of the study). Adjusted for: age, sex, race, education level, marital status, police rank, and chronotype. ALT: alanine aminotransferase. CRP: C-reactive protein. HDL: high-density lipoprotein. TSH: thyroid stimulating hormone. SDNN: standard deviation of normal-to-normal heart beat intervals. CI: confidence interval. DF: degrees of freedom.

APPENDIX - Aim 3

Table A.3.1: Descriptive Statistics of BCOPS Participants by Predicted Adaptation Status and Study Visit, BCOPS Study 2024

Variable	Exam 1			Exam 2			Exam 3		
	Adapted (N=280)	Semi-Maladapted (N=163)	Maladapted (N=80)	Adapted (N=256)	Semi-Maladapted (N=181)	Maladapted (N=86)	Adapted (N=273)	Semi-Maladapted (N=174)	Maladapted (N=76)
Age									
Mean (SD)	41 (9)	43 (9)	43 (8)	45 (9)	49 (9)	48 (9)	46 (10)	52 (10)	52 (10)
Median	40	42	43	46	50	48	46	53	51
(Min, Max)	(21, 74)	(24, 70)	(27, 65)	(25, 68)	(26, 73)	(23, 72)	(27, 76)	(21, 75)	(30, 78)
Missing	39 (14%)	16 (10%)	4 (5%)	122 (48%)	65 (36%)	36 (42%)	146 (54%)	96 (55%)	41 (54%)
Race/Ethnicity									
European American	195 (70%)	128 (79%)	55 (69%)	113 (44%)	87 (48%)	37 (43%)	101 (37%)	62 (36%)	32 (42%)
African American	50 (18%)	23 (14.1%)	18 (22.5%)	20 (7.8%)	25 (13.8%)	13 (15%)	24 (8.8%)	15 (8.6%)	3 (4%)
Hispanic	3 (1%)	3 (2%)	3 (4%)	1 (0.4%)	4 (2%)	0	2 (1%)	1 (1%)	0
Missing	32 (11%)	9 (6%)	4 (5%)	122 (48%)	65 (36%)	36 (42%)	146 (54%)	96 (55%)	41 (54%)
Sex									
Female	80 (29%)	35 (22%)	22 (28%)	75 (29%)	42 (23%)	20 (23%)	71 (26%)	44 (25%)	22 (29%)
Male	200 (71%)	128 (79%)	58 (73%)	181 (71%)	139 (77%)	66 (77%)	202 (74%)	130 (75%)	54 (71%)
Marital Status									
Single	29 (10%)	18 (11%)	8 (10%)	15 (6%)	16 (9%)	7 (8%)	18 (7%)	11 (6%)	3 (4%)
Married	172 (61%)	112 (67%)	54 (68%)	87 (34%)	80 (44%)	36 (42%)	89 (33%)	56 (32%)	23 (30%)
Divorced	35 (13%)	15 (9%)	11 (14%)	32 (13%)	18 (10%)	7 (8%)	20 (7%)	11 (6%)	8 (11%)
Missing	44 (16%)	18 (11%)	7 (9%)	122 (48%)	67 (37%)	36 (42%)	146 (54%)	96 (55%)	42 (55%)
Education Level									

Table A.3.1: Descriptive Statistics of BCOPS Participants by Predicted Adaptation Status and Study Visit, BCOPS Study 2024

Variable	Exam 1			Exam 2			Exam 3		
	Adapted (N=280)	Semi-Maladapted (N=163)	Maladapted (N=80)	Adapted (N=256)	Semi-Maladapted (N=181)	Maladapted (N=86)	Adapted (N=273)	Semi-Maladapted (N=174)	Maladapted (N=76)
<=12 yrs	21 (7.5%)	20 (12.3%)	9 (11.3%)	6 (2.3%)	10 (5.5%)	8 (9.3%)	2 (0.7%)	6 (3.4%)	3 (3.9%)
College < 4 yrs	128 (45.7%)	83 (50.9%)	38 (47.5%)	72 (28.1%)	65 (35.9%)	14 (16.3%)	58 (21.2%)	42 (24.1%)	22 (28.9%)
College 4+ yrs	87 (31.1%)	42 (25.8%)	26 (32.5%)	56 (21.9%)	41 (22.7%)	28 (32.6%)	67 (24.5%)	30 (17.2%)	10 (13.2%)
Missing	44 (15.7%)	18 (11.0%)	7 (8.8%)	122 (47.7%)	65 (35.9%)	36 (41.9%)	146 (53.5%)	96 (55.2%)	41 (53.9%)
Police Rank									
Police officer	176 (62.9%)	91 (55.8%)	45 (56.3%)	78 (30.5%)	64 (35.4%)	29 (33.7%)	68 (24.9%)	34 (19.5%)	17 (22.4%)
Sgt/Lt/Capt	36 (12.9%)	24 (14.7%)	12 (15.0%)	31 (12.1%)	20 (11.0%)	7 (8.1%)	32 (11.7%)	20 (11.5%)	8 (10.5%)
Detective	17 (6.1%)	23 (14.1%)	10 (12.5%)	22 (8.6%)	27 (14.9%)	8 (9.3%)	25 (9.2%)	18 (10.3%)	10 (13.2%)
Executive	2 (0.7%)	6 (3.7%)	3 (3.8%)	1 (0.4%)	4 (2.2%)	2 (2.3%)	1 (0.4%)	4 (2.3%)	0 (0%)
Other	1 (0.4%)	2 (1.2%)	2 (2.5%)	1 (0.4%)	0 (0%)	2 (2.3%)	0 (0%)	0 (0%)	0 (0%)
Missing	48 (17.1%)	17 (10.4%)	8 (10.0%)	123 (48.0%)	66 (36.5%)	38 (44.2%)	147 (53.8%)	98 (56.3%)	41 (53.9%)
Military Service									
No	177 (63.2%)	101 (62.0%)	56 (70.0%)	104 (40.6%)	89 (49.2%)	37 (43.0%)	109 (39.9%)	57 (32.8%)	29 (38.2%)
Yes	58 (20.7%)	45 (27.6%)	17 (21.3%)	29 (11.3%)	27 (14.9%)	13 (15.1%)	18 (6.6%)	21 (12.1%)	6 (7.9%)
Missing	45 (16.1%)	17 (10.4%)	7 (8.8%)	123 (48.0%)	65 (35.9%)	36 (41.9%)	146 (53.5%)	96 (55.2%)	41 (53.9%)
No. of Sick Days									
Mean (SD)	1.05 (0.908)	0.923 (0.946)	0.849 (0.967)	0.853 (0.867)	0.625 (0.861)	0.755 (0.902)	0.874 (0.777)	0.744 (0.874)	0.686 (0.718)
Median (Min, Max)	1.00 (0, 4.00)	1.00 (0, 4.00)	1.00 (0, 4.00)	1.00 (0, 4.00)	0 (0, 4.00)	0 (0, 3.00)	1.00 (0, 3.00)	0.500 (0, 3.00)	1.00 (0, 2.00)
Missing	48 (17.1%)	21 (12.9%)	7 (8.8%)	127 (49.6%)	69 (38.1%)	37 (43.0%)	146 (53.5%)	96 (55.2%)	41 (53.9%)
Dominant Shift									
Evening	72 (25.7%)	49 (30.1%)	21 (26.3%)	50 (19.5%)	29 (16.0%)	20 (23.3%)	42 (15.4%)	25 (14.4%)	14 (18.4%)

Table A.3.1: Descriptive Statistics of BCOPS Participants by Predicted Adaptation Status and Study Visit, BCOPS Study 2024

Variable	Exam 1			Exam 2			Exam 3		
	Adapted (N=280)	Semi-Maladapted (N=163)	Maladapted (N=80)	Adapted (N=256)	Semi-Maladapted (N=181)	Maladapted (N=86)	Adapted (N=273)	Semi-Maladapted (N=174)	Maladapted (N=76)
Day	89 (31.8%)	63 (38.7%)	36 (45.0%)	53 (20.7%)	63 (34.8%)	23 (26.7%)	60 (22.0%)	38 (21.8%)	14 (18.4%)
Night	58 (20.7%)	27 (16.6%)	15 (18.8%)	30 (11.7%)	23 (12.7%)	7 (8.1%)	24 (8.8%)	15 (8.6%)	7 (9.2%)
Missing	61 (21.8%)	24 (14.7%)	8 (10.0%)	123 (48.0%)	66 (36.5%)	36 (41.9%)	147 (53.8%)	96 (55.2%)	41 (53.9%)
Tertiled Second Job									
Low	156 (55.7%)	91 (55.8%)	50 (62.5%)	90 (35.2%)	78 (43.1%)	36 (41.9%)	77 (28.2%)	49 (28.2%)	23 (30.3%)
Middle	20 (7.1%)	13 (8.0%)	5 (6.3%)	7 (2.7%)	9 (5.0%)	4 (4.7%)	18 (6.6%)	6 (3.4%)	0 (0%)
High	55 (19.6%)	41 (25.2%)	18 (22.5%)	31 (12.1%)	23 (12.7%)	9 (10.5%)	32 (11.7%)	23 (13.2%)	12 (15.8%)
Missing	49 (17.5%)	18 (11.0%)	7 (8.8%)	128 (50.0%)	71 (39.2%)	37 (43.0%)	146 (53.5%)	96 (55.2%)	41 (53.9%)
Tertiled Overtime Hours									
Low	139 (49.6%)	58 (35.6%)	17 (21.3%)	164 (64.1%)	91 (50.3%)	48 (55.8%)	181 (66.3%)	114 (65.5%)	48 (63.2%)
Middle	73 (26.1%)	47 (28.8%)	22 (27.5%)	43 (16.8%)	34 (18.8%)	21 (24.4%)	42 (15.4%)	24 (13.8%)	13 (17.1%)
High	56 (20.0%)	53 (32.5%)	38 (47.5%)	35 (13.7%)	51 (28.2%)	16 (18.6%)	37 (13.6%)	32 (18.4%)	12 (15.8%)
Missing	12 (4.3%)	5 (3.1%)	3 (3.8%)	14 (5.5%)	5 (2.8%)	1 (1.2%)	13 (4.8%)	4 (2.3%)	3 (3.9%)
Dichotomized Dominant Shift									
Day	89 (31.8%)	63 (38.7%)	36 (45.0%)	53 (20.7%)	63 (34.8%)	23 (26.7%)	60 (22.0%)	38 (21.8%)	14 (18.4%)
Evenings & Nights	130 (46.4%)	76 (46.6%)	36 (45.0%)	80 (31.3%)	52 (28.7%)	27 (31.4%)	66 (24.2%)	40 (23.0%)	21 (27.6%)
Missing	61 (21.8%)	24 (14.7%)	8 (10.0%)	123 (48.0%)	66 (36.5%)	36 (41.9%)	147 (53.8%)	96 (55.2%)	41 (53.9%)
Tertiled No. of Shift Changes									
Low	134 (48%)	70 (43%)	28 (35%)	151 (59%)	107 (59%)	49 (57%)	178 (65%)	117 (67%)	49 (65%)
Middle	57	44	24	50	32	13	41	23	14

Table A.3.1: Descriptive Statistics of BCOPS Participants by Predicted Adaptation Status and Study Visit, BCOPS Study 2024

Variable	Exam 1			Exam 2			Exam 3		
	Adapted (N=280)	Semi-Maladapted (N=163)	Maladapted (N=80)	Adapted (N=256)	Semi-Maladapted (N=181)	Maladapted (N=86)	Adapted (N=273)	Semi-Maladapted (N=174)	Maladapted (N=76)
	(20%)	(27%)	(30%)	(20%)	(18%)	(15%)	(15%)	(13%)	(18%)
High	77 (28%)	44 (27%)	25 (31%)	41 (16%)	37 (20%)	23 (27%)	41 (15%)	30 (17%)	10 (13%)
Missing	12 (4%)	5 (3%)	3 (4%)	14 (6%)	5 (3%)	1 (1%)	13 (5%)	4 (2%)	3 (4%)
Tertiled Occupational Stress									
Low	58 (20.7%)	31 (19.0%)	6 (7.5%)	33 (12.9%)	18 (9.9%)	7 (8.1%)	26 (9.5%)	15 (8.6%)	9 (11.8%)
Middle	130 (46.4%)	88 (54.0%)	55 (68.8%)	87 (34.0%)	75 (41.4%)	35 (40.7%)	84 (30.8%)	50 (28.7%)	22 (28.9%)
High	27 (9.6%)	19 (11.7%)	10 (12.5%)	7 (2.7%)	16 (8.8%)	7 (8.1%)	16 (5.9%)	13 (7.5%)	4 (5.3%)
Missing	65 (23.2%)	25 (15.3%)	9 (11.3%)	129 (50.4%)	72 (39.8%)	37 (43.0%)	147 (53.8%)	96 (55.2%)	41 (53.9%)
Alcoholic Beverages per Week									
Quartiles 1-3	165 (58.9%)	106 (65.0%)	59 (73.8%)	102 (39.8%)	83 (45.9%)	40 (46.5%)	95 (34.8%)	55 (31.6%)	29 (38.2%)
Quartile 4	67 (23.9%)	36 (22.1%)	14 (17.5%)	31 (12.1%)	31 (17.1%)	10 (11.6%)	29 (10.6%)	20 (11.5%)	6 (7.9%)
Missing	48 (17.1%)	21 (12.9%)	7 (8.8%)	123 (48.0%)	67 (37.0%)	36 (41.9%)	149 (54.6%)	99 (56.9%)	41 (53.9%)
Weekly Servings of Fat									
Quartiles 1-3	211 (75.4%)	132 (81.0%)	65 (81.3%)	122 (47.7%)	103 (56.9%)	47 (54.7%)	111 (40.7%)	68 (39.1%)	32 (42.1%)
Quartile 4	22 (7.9%)	13 (8.0%)	7 (8.8%)	11 (4.3%)	12 (6.6%)	3 (3.5%)	14 (5.1%)	8 (4.6%)	3 (3.9%)
Missing	47 (16.8%)	18 (11.0%)	8 (10.0%)	123 (48.0%)	66 (36.5%)	36 (41.9%)	148 (54.2%)	98 (56.3%)	41 (53.9%)
Weekly Servings of Vegetables									
Quartiles 1-3	204 (72.9%)	132 (81.0%)	61 (76.3%)	116 (45.3%)	102 (56.4%)	47 (54.7%)	102 (37.4%)	68 (39.1%)	27 (35.5%)
Quartile 4	28 (10.0%)	12 (7.4%)	11 (13.8%)	17 (6.6%)	12 (6.6%)	3 (3.5%)	23 (8.4%)	8 (4.6%)	8 (10.5%)

This resource was prepared by the author(s) using Federal funds provided by the U.S. Department of Justice. Opinions or points of view expressed are those of the author(s) and do not necessarily reflect the official position or policies of the U.S. Department of Justice.

Table A.3.1: Descriptive Statistics of BCOPS Participants by Predicted Adaptation Status and Study Visit, BCOPS Study 2024

Variable	Exam 1			Exam 2			Exam 3		
	Adapted (N=280)	Semi-Maladapted (N=163)	Maladapted (N=80)	Adapted (N=256)	Semi-Maladapted (N=181)	Maladapted (N=86)	Adapted (N=273)	Semi-Maladapted (N=174)	Maladapted (N=76)
Missing	48 (17.1%)	19 (11.7%)	8 (10.0%)	123 (48.0%)	67 (37.0%)	36 (41.9%)	148 (54.2%)	98 (56.3%)	41 (53.9%)
Weekly Servings of Fruit									
Quartiles 1-3	212 (75.7%)	131 (80.4%)	63 (78.8%)	117 (45.7%)	95 (52.5%)	47 (54.7%)	103 (37.7%)	71 (40.8%)	27 (35.5%)
Quartile 4	20 (7.1%)	13 (8.0%)	9 (11.3%)	16 (6.3%)	19 (10.5%)	3 (3.5%)	23 (8.4%)	5 (2.9%)	8 (10.5%)
Missing	48 (17.1%)	19 (11.7%)	8 (10.0%)	123 (48.0%)	67 (37.0%)	36 (41.9%)	147 (53.8%)	98 (56.3%)	41 (53.9%)
Physical Activity Level									
Low	13 (4.6%)	4 (2.5%)	4 (5.0%)	0 (0%)	0 (0%)	0 (0%)	11 (4.0%)	6 (3.4%)	2 (2.6%)
Mid	60 (21.4%)	50 (30.7%)	28 (35.0%)	37 (14.5%)	29 (16.0%)	12 (14.0%)	33 (12.1%)	23 (13.2%)	11 (14.5%)
High	150 (53.6%)	86 (52.8%)	38 (47.5%)	78 (30.5%)	73 (40.3%)	32 (37.2%)	82 (30.0%)	49 (28.2%)	22 (28.9%)
Missing	57 (20.4%)	23 (14.1%)	10 (12.5%)	141 (55.1%)	79 (43.6%)	42 (48.8%)	147 (53.8%)	96 (55.2%)	41 (53.9%)
Antidepressant Use									
No	255 (91.1%)	150 (92.0%)	69 (86.3%)	239 (93.4%)	175 (96.7%)	83 (96.5%)	260 (95.2%)	168 (96.6%)	73 (96.1%)
Yes	21 (7.5%)	12 (7.4%)	9 (11.3%)	12 (4.7%)	5 (2.8%)	2 (2.3%)	10 (3.7%)	5 (2.9%)	0 (0%)
Missing	4 (1.4%)	1 (0.6%)	2 (2.5%)	5 (2.0%)	1 (0.6%)	1 (1.2%)	3 (1.1%)	1 (0.6%)	3 (3.9%)

Table A.3.2. Odds of Maladaptation or Semi-Maladaptation among Officers with Categorical Biomarker Outcomes, by Study Visit, BCOPS Cohort, 2024						
Outcome	**Odds Ratio of Maladaptation Status**					
	Exam 1		**Exam 2**		**Exam 3**	
	Maladapted vs. Adapted	Semi-Mal vs. Adapted	Maladapted vs. Adapted	Semi-Mal vs. Adapted	Maladapted vs. Adapted	Semi-Mal vs. Adapted
Cardiometabolic Measures						
Metabolic Syndrome	0.943	1.031	0.961	1.155	0.932	0.860
Abdominal Obesity	1.229	1.308	0.851	1.285	0.867	0.895
High Blood Pressure	0.980	1.279	1.222	1.194	0.937	0.981
High Fasting Glucose	0.730	0.796	0.882	1.032	1.256	0.703
High HDL Cholesterol	0.817	0.701	1.046	1.056	0.658	1.649
High Triglycerides	1.287	1.044	0.781	0.778	0.575	1.048
Inflammatory Cytokines						
CRP ≥3 (mg/L)	1.116	1.192	0.777	0.698	1.721	1.088

Adjusted by age, sex, race, education level, marital status, police rank, and chronotype. *p<0.05, **p<0.01, ***p<0.001. HDL: high-density lipoprotein. CRP: C-reactive protein.

AIM 4 - *Develop recommendations for implementing evidence-based strategies for adapting to atypical work hours that influence chronic disease indicators in police officers*.

Outcome Aim 4

The BCOPS cohort is a unique resource for examining the longitudinal impacts of atypical work hours on early indicators of chronic disease in a high-risk population of law enforcement personnel. BCOPS participants have contributed an extensive array of psychometric, physiological, sociodemographic, and lifestyle/behavioral data to this effort. The analyses completed for this investigation spanned a median of 12 years of follow-up over three clinic visits, yielding ~1,569 data records for analysis. This study included 464 participants at the initial study visit (Exam 1), 300 participants at Exam 2, 240 at Exam 3, and 176 cohort members participated in all three data collection cycles. A novel aspect of this cohort is the availability of multiple factors that characterize atypical work hours, including measures of the cumulative amount of time working on evening, night, and day shifts, as well as the number of shift changes over time, cumulative overtime hours, and the amount of time devoted to secondary employment (second jobs). The authors of this study examined the impacts of each of these work factors on preclinical disease biomarkers over time, and also developed and evaluated an Occupational Stress score that combined each of the atypical work factors into a single classification that enabled an evaluation of the collective impacts of these occupational exposures. Another novel aspect of this study was implementation of strategies that classified participants as either adapted or maladapted to shiftwork, and the examination of changes in disease biomarkers in each of these groups. Despite an extensive literature on the impacts of shiftwork, few studies have attempted to characterize longitudinal changes in chronic disease indicators among adapted and maladapted shiftworkers. For this study, a selected set of symptom indicator variables were used to statistically define individuals with and without adaptation, which facilitated examination of patterns of shiftwork adaptation over time, as well as individual characteristics associated with those patterns, and their relationship with chronic disease indicators during the period of follow-up.

Discussion

Aim 1

Aim 1 analyses tested the hypotheses that atypical work factors (shiftwork, shift changes, cumulative overtime hours, secondary jobs, or a combined Occupational Stress score) can adversely impact immune, endocrine, metabolic, neurologic, or epigenetic chronic disease indicators. Several biomarkers were altered in response to one or more of these work factors. Those in the upper tertile of shift changes had increases in the liver function enzymes (ALT at Exams 2-3, and AST at Exam 2), as well as increases in total cholesterol (Exams 2-3) and LDL cholesterol (Exam 3). Hypothesized reductions in several HRV measures (SDNN, RMSSD, LF-HRV, HF-HRV) were also observed among those with elevated shift changes. Among those working evenings or nights as their dominant shift, RMSSD and LF-HRV were lower at Exam 3 relative to participants working days. Those in the upper tertile of cumulative overtime hours had elevated LDL cholesterol and lower LF-HRV and HF-HRV at Exam 3. Working a second job was associated with elevated total cholesterol and cholesterol:HDL ratios (Exam 1 only), and with reduced adiponectin and TSH (Exam 3). Those with high or intermediate Occupational Stress scores had higher levels of total and LDL cholesterol at Exams 1 and 3 relative to the low Occupational Stress group. Occupational stress was also associated with higher cholesterol:HDL ratios and elevated CRP but only at Exam 1. Finally, hypothesized reductions in all HRV metrics occurred at Exam 3 among those in the high Occupational Stress group. All models were adjusted for age, sex, race, education, marital status, police rank, and chronotype.

Results from these analyses indicate that changes in cholesterol and HRV were among the most consistent and robust findings, particularly in response to shift changes and the Occupational Stress measure, which combined exposure to all the atypical work factors that were examined in this study. HRV is a measure of changes in heart rate over time that quantifies both sympathetic and parasympathetic autonomic nervous system (ANS) activity.[36-38] Sympathetic nervous system (SNS) activity is heightened during the stress response, and parasympathetic activity generally opposes sympathetic output.[36,39] Elevated HRV is an established biomarker of optimal cardiovascular resilience and health, whereas low HRV has been associated with multiple adverse health outcomes and increased mortality risk.[40-49] The ANS plays a vital role in regulating cardiovascular and metabolic function, including the disposition of blood glucose and lipids, as well as the secretion of immune and endocrine mediators that interact with these systems. Reduced HRV has been associated with undesirable changes in several metabolic syndrome components including waist circumference, triglycerides, HDL cholesterol, blood pressure, and serum glucose.[50-52] Reductions in HRV serve as an early indicator of chronic disease risk and other adverse health outcomes.[43,46-49] Our recent study showing an association between low HRV and metabolic syndrome was consistent with other studies that examined this relationship.[53] The odds of metabolic syndrome were strongest among those with both low HRV (LF-HRV, SDNN) and poor sleep quality,[53] conditions that are common in shiftworking occupations including law enforcement.[18,54-59]

Aim 2

Data collection for Aim 2 included a newly developed, cross-sectional survey among BCOPS participants to gather information on adaptation strategies for atypical work hours. Participants provided rankings of their adaptation strategies, and descriptive statistics were used to identify the most prevalent tactics used. Complementary methods were used to characterize adaptation or maladaptation. These included direct questions targeting these issues, as well as latent class analysis (LCA), which grouped participants into adapted and maladapted groups based on prespecified symptom profiles. Statistical analyses were performed to identify sociodemographic, behavioral, lifestyle, and occupational factors, psychosocial traits, and personal/familial circumstances that differed between the adapted and maladapted groups, and subsequent analyses examined differences in preclinical chronic disease biomarkers (cardiometabolic, endocrine, inflammatory/immune, neurologic, epigenetic) among those in the adapted and maladapted groups.

The most highly ranked adaptation strategies among respondents to the Aim 2 survey were behaviors targeting sleep, including ‘getting the right amount’, and having a ‘good sleep environment’ and ‘good sleep timing’. Other strategies that were ranked as important included appropriate diet and exercise, although it is noteworthy that rankings for getting the right amount of sleep were two to three times greater than any other adaptation strategy. Items that were ranked more highly among maladapted relative to adapted personnel included more frequent use of sleep aids (general model) and caffeinated beverages (general and police specific). These observations are consistent with other studies that have reported sleep disruption as the most common and debilitating issue reported among populations participating in shiftwork.[57-59]

Results from the Aim 2 latent class analysis (LCA) identified two groups with distinct symptom profiles indicative of shiftwork adaptation or maladaptation. Unexpectedly, there were no differences in the responses these groups provided to direct questions about shiftwork adaptation. These results suggest that participants may have been reluctant to admit that they were maladapted in the survey. Alternatively, the LCA-derived symptom profiles may not have been related to shiftwork adaptation. However, those with LCA-derived shiftwork maladaptation group were more likely to work evenings or nights, and the average number of shift changes was more than two times greater than the adapted group in both the police specific and general models. In addition, those in the maladapted group had a wide range of characteristics that are consistent with a maladaptation profile, including more: burnout, effort-reward imbalance, work-family imbalance, family conflict, daily police hassles, impacts of significant life events, work related injuries, and adverse childhood events; as well as less hardiness, familial organization, supervisor or coworker support, and lower mindfulness ratings. These observations provide evidence that the LCA-derived groups adequately identified adapted and maladapted personnel, and supported the use of these groups in subsequent analyses.

Differences in several biomarkers of interest were noted between the adapted and maladapted groups identified for Aim 2, including elevated IL-6 and cholesterol:HDL ratios, greater metabolic syndrome severity scores, and a tendency towards elevated triglycerides and more metabolic syndrome components among maladapted relative to adapted participants. The sample size (N=120, with 8% to 14% maladapted) may have limited power to detect statistically significant differences in some of the other population characteristics or biomarkers. However, differences that were identified for several biomarkers evaluated in Aim 2 were consistent with those identified in Aim 1.

Aim 3

It may be logical to assume that maladapted shiftworkers are at greater risk of developing adverse health outcomes (and therefore earlier or more severe changes in chronic disease biomarkers) relative to adapted workers. However, this possibility has not been thoroughly investigated in prior studies. To the author's knowledge, Aim 3 analyses are the first to examine longitudinal trajectories of symptoms associated with adaptation/maladaptation, and to examine their effect on chronic disease indicators over time. Exploratory latent transition analysis (LTA) was used for this purpose with prespecified symptoms (anxiety, police stress, perceived stress, vital exhaustion, sleep quality, depression, social support) that were ascertained among participants in the BCOPS cohort. Assignment of participants to different LTA groups was based on estimated rather than observed data. Results from this analysis identified distinct groups with symptom profiles indicative of adaptation and maladaptation, as well as a third group of partially adapted (Semi-Maladapted) personnel. This intermediate pattern was characterized by maladaptive characteristics including poor sleep quality, elevated stress and more vital exhaustion, while other symptoms (depression, anxiety) reflected those in the adapted group. These results suggested that Semi-Maladapted individuals may have been in a transient state with the possibility of transitioning into either maladapted or adapted conditions depending on their intrinsic or extrinsic circumstances. The transition matrix for this analysis predicted that few participants migrated into the Maladapted class during the study period. Instead, a sizeable portion of Semi-Maladapted and Maladapted workers (45% and 40%, respectively) transitioned into the Adapted group, and at steady state only ~6% of those in the Maladapted group were expected to remain in that group. This suggests that cohort members may have been aware of the issues concerning maladaptation to atypical work hours and were motivated to avoid that condition due to self-awareness, prodromal feelings of malaise, or prior knowledge of the potential risks. Participants in the Always Adapted and Maladapted to Adapted groups tended to be older and have >20 years of law enforcement work experience relative to other groups.

Results from the Aim 3 biomarker analyses indicated that those in the Maladapted group at Exam 2 had reductions in parasympathetic ANS activity (RMSSD, HF-HRV) relative to the Adapted group. At Exam 3, those in the Maladapted group had elevated LF-HRV compared to the Adapted group, possibly indicating a stress-induced increase in sympathetic ANS activity. This change was observed in tandem with elevated CRP levels among Maladapted personnel at Exam 3, consistent with stress-related changes in this inflammation biomarker that have been observed in other studies.[60,61]

When biomarkers were further evaluated using adapted or maladapted transition patterns assessed over the entire study period (Always Adapted, Always Maladapted, Always Semi-Maladapted, Adapted to Maladapted, Maladapted to Adapted, Other), thyroid stimulating hormone (TSH), and the liver function enzyme, alanine aminotransferase (ALT) and were both elevated among those who were Always Maladapted relative to the Always Adapted group. TSH is commonly used for thyroid function screening, and elevated levels may indicate a deficiency in the metabolic hormone that is targeted by TSH, thyroxine, although no change in the thyroxine precursor, triiodothyronine (T3) was observed in this study. Elevated ALT is commonly used to screen for early signs of liver injury and non-alcoholic fatty liver disease, as well as other more serious hepatic diseases such as steatohepatitis and liver cirrhosis.[62] Other changes in the biomarkers that were evaluated included increases in total cholesterol among those in the Maladapted to Adapted group, and a reduction in SDNN among those in the 'Other' transition group, which represented those with more complex adaptation/maladaptation transition patterns that changed more than once during the study period.

Results from Aim 3 analyses suggest that the consequences adaptation or maladaptation to atypical work hours over periods up to a decade or more may be complicated by transitions between various psychophysiological states as police navigate their work activities and other life circumstances over time. Changes in biomarkers that were inconsistent or in the opposite direction of what was hypothesized may have been due to compensatory or rebound effects. Another possible explanation for unexpected or inconsistent results includes the possibility of Type 2 error. The results indicated that those classified as Maladapted or Semi-Maladapted decreased over time, although the extent to which these participants may have transitioned away from their position is uncertain. These uncertainties also may have impacted the ability to detect consistent changes in biomarkers, which may have occurred due to the compensatory, nonlinear nature of the physiological processes involved, and the perpetual adjustment and re-adjustment of those processes to existing circumstances (in a manner similar to circadian rhythm disturbances such as jet lag but on a longer time scale). If more severely impacted workers migrated to a new position or changed jobs entirely, the resulting effect may have introduced a healthy survivor bias. These possibilities may help explain some of the unexpected or inconsistent results that were observed in this analysis. For example, total and LDL cholesterol were both elevated in the Semi-Maladapted group at Exam 1 but not other study visits. This may have been related to a transition of Semi-Maladapted personnel out of that group. Similarly, those in the Maladapted group had estimated blood glucose and HbA1C levels that were elevated at Exam 2 but not other study visits.

Expected Applicability

There are several noteworthy themes that emerged from analyses performed for Aims 1-3. Results from this study provide evidence that prolonged exposure to shift changes is a key driver of maladaptation. Another important finding was that extensive shift changes can elicit multiple detrimental effects of on chronic disease biomarkers. In Aim 1, those in the upper tertile of shift changes had elevated total cholesterol (Exams 2-3) and LDL cholesterol (Exam 3). Maladapted participants in Aim 2 had twice as many shift changes as the adapted group, they were more likely to work evenings or nights, and they exhibited a wide range of other symptoms and characteristics consistent with maladaptation. Unfavorable changes in biomarkers that were observed among maladapted participants in Aim 2 included elevated IL-6, triglycerides, and cholesterol:HDL ratios, as well as higher metabolic syndrome severity scores, and more positive metabolic syndrome components, which are similar, though not identical, to the altered metabolic processes observed among Aim 1 participants. Aim 1 analyses identified increases in AST (Exam 2) and ALT (Exams 2 and 3) among those in the upper tertile of shift changes, which is consistent with increases in ALT that were observed in Aim 3 among those in the Always Maladapted group. Note that those in the Always Maladapted, Always Semi-Maladapted, and Adapted to Maladapted groups in Aim 3 were predominantly in the upper tertile of shift changes. Alternatively, those in the Always Adapted group were in the lowest shift change tertile, and those who transitioned from being Maladapted to Adapted had fewer shift changes relative to other groups. Reductions in multiple HRV parameters were also observed among those with elevated shift changes (Aim 1). These observations suggest that shift changes are a major driver of maladaptation, and that these impacts drive changes in several important pathophysiological processes among those involved in atypical work. Taken together, the results indicate that efforts to minimize shift changes would elicit a salubrious benefit to law enforcement personnel.

In addition to reductions in multiple HRV measures that were observed in Aim 1 among those with elevated shift changes, reductions in HRV were also observed among those working evenings or nights as their dominant shift (RMSSD and LF-HRV at Exam 3). In addition, those in the upper tertile of cumulative overtime hours had elevated LDL cholesterol as well as lower LF-HRV and HF-HRV (Exam 3). Those with an elevated Occupational Stress classification had elevated LDL and total cholesterol (Exams 1, 3) as well as reductions in all of the HRV measures (Exam 3). These robust findings highlight the potential for targeting HRV for reducing or preventing cardiometabolic impacts associated with atypical work hours. Interventions that increase HRV by boosting vagal parasympathetic tone may elicit a number of health benefits including improved mental and physiological well-being, and reduced mortality risk.[63-65] Methods that stimulate parasympathetic tone and improve ANS homeostasis, such as HRV biofeedback, may serve as an effective, low-cost strategy not only for improving HRV but also the cardiovascular and metabolic processes that are regulated by ANS activity.[66-69]

HRV biofeedback has also been suggested as effective method for improving sleep and facilitating shift work adaptation.[55,70]

Various behaviors targeting improved sleep were identified as important adaptation strategy among Aim 2 survey respondents. Other strategies that were ranked as important included diet and exercise, and physical activity was more common among those in the Always Adapted group (Aim 3) than other groups. Appropriately timed food consumption and exercise can both promote sleep. Thus, greater facilitation of these lifestyle behaviors would derive multiple benefits. Women were over-represented in the Always Maladapted and Adapted to Maladapted groups relative to the other groups (Aim 3), which suggests a need for tailored interventions targeting this population. Finally, results from Aim 2 identified multiple mental and psychosocial factors that were more prevalent among those in the maladapted group, which indicates that interventions targeting improved mental health would benefit law enforcement personnel.

Collaborating Organizations:

Dept. of Epidemiology, School of Population Health, Virginia Commonwealth University, Richmond, VA.

Dept. of Biostatistics, School of Population Health, Virginia Commonwealth University Richmond, VA.

Dept. of Epidemiology and Biostatistics, Arnold School of Public Health, University of South Carolina, Columbia, SC, USA.

Literature Cited

1. Portaluppi F, Smolensky MH, Touitou Y. Ethics and methods for biological rhythm research on animals and human beings. Chronobiol Int 2010;27:1911-29.
2. Sallis JF, Haskell WL, Wood PD, Fortmann SP, Rogers T, Blair SN, Paffenbarger RS, Jr. Physical activity assessment methodology in the Five-City Project. Am J Epidemiol 1985;121:91-106.
3. Buysse DJ, Reynolds CF, 3rd, 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.
4. Grandner MA, Kripke DF, Yoon IY, Youngstedt SD. Criterion validity of the Pittsburgh Sleep Quality Index: Investigation in a non-clinical sample. Sleep Biol Rhythms 2006;4:129-39.
5. Spielberger CD, Westberry LG, Grier KS, Greenfield G. The Police Stress Survey: Sources of stress in law enforcement. Tampa, FL: Human Resources Institute Monograph Series Three, No. 6; 1981.
6. Appels A, Mulder P. Excess fatigue as a precursor of myocardial infarction. Eur Heart J 1988;9:758-64.
7. Cohen S, Kamarck T, Mermelstein R. A global measure of perceived stress. J Health Soc Behav 1983;24:385-96.
8. Van Dam NT, Earleywine M. Validation of the Center for Epidemiologic Studies Depression Scale--Revised (CESD-R): Pragmatic depression assessment in the general population. Psychiatry Res 2011;186:128-32.
9. Cutrona C, Russell D. The provisions of social relationships and adaptation to stress. In: Advances in Personal Relationships: Greenwich (CT): JAI Press; 1983:37-67.
10. Costa P, McCrae R. The NEO-PI/NEO-FFI manual supplement. Odessa, FL: Psychological Assessment Resources; 1989.
11. Zillig LMP, Hemenover SH, Dienstbier RA. What do we assess when we assess a Big 5 Trait? A content analysis of the affective, behavioral, and cognitive processes represented in Big 5 personality inventories. Personality and Social Psychology Bulletin 2016;28:847-58.
12. Bartone PT. Test-retest reliability of the dispositional resilience scale-15, a brief hardiness scale. Psychol Rep 2007;101:943-4.
13. Charalampous K, Kokkinos CM, Panayiotou G. The Family Environment Scale: Resolving Psychometric Problems through an examination of a Greek translation. The International Journal of Educational and Psychological Assessment 2013;13:81-99.
14. Lange LA, Carlson CS, Hindorff LA, Lange EM, Walston J, Durda JP, Cushman M, Bis JC, Zeng D, Lin D, Kuller LH, Nickerson DA, Psaty BM, Tracy RP, Reiner AP. Association of polymorphisms in the CRP gene with circulating C-reactive protein levels and cardiovascular events.[see comment]. JAMA 2006;296:2703-11.
15. NCEP. Third report of the National Cholesterol Education Program (NCEP) expert panel on detection, evaluation, and treatment of high blood cholesterol in adults (Adult treatment panel III). Circulation 2002;106:3143-421.
16. Gurka MJ, Lilly CL, Oliver MN, DeBoer MD. An examination of sex and racial/ethnic differences in the metabolic syndrome among adults: a confirmatory factor analysis and a resulting continuous severity score. Metabolism 2014;63:218-25.

17. Nevels TL, Burch JB, Wirth MD, Ginsberg JP, McLain AC, Andrew ME, Allison P, Fekedulegn D, Violanti JM. Shift Work Adaptation Among Police Officers: The BCOPS Study. Chronobiol Int 2021;38:907-23.

18. Andrew ME, Shengqiao L, Wactawski-Wende J, Dorn JP, Mnatsakanova A, Charles LE, Fekedulegn D, Miller DB, Violanti JM, Burchfiel CM, Sharp DS. Adiposity, muscle, and physical activity: predictors of perturbations in heart rate variability. Am J Hum Biol 2013;25:370-7.

19. Molzof HE, Wirth MD, Burch JB, Shivappa N, Hebert JR, Johnson RL, Gamble KL. The impact of meal timing on cardiometabolic syndrome indicators in shift workers. Chronobiol Int 2017;34:337-48.

20. Flo E, Bjorvatn B, Folkard S, Moen BE, Gronli J, Nordhus IH, Pallesen S. A reliability and validity study of the Bergen Shift Work Sleep Questionnaire in nurses working three-shift rotations. Chronobiol Int 2012;29:937-46.

21. Smith L, Norman P, Folkard S. Predicting shiftwork-related outcomes: shiftwork locus of control and circadian type. J Hum Ergol (Tokyo) 2001;30:59-64.

22. Gamble KL, Motsinger-Reif AA, Hida A, Borsetti HM, Servick SV, Ciarleglio CM, Robbins S, Hicks J, Carver K, Hamilton N, Wells N, Summar ML, McMahon DG, Johnson CH. Shift work in nurses: contribution of phenotypes and genotypes to adaptation. PLoS One 2011;6:e18395.

23. Petrov ME, Clark CB, Molzof HE, Johnson RL, Jr., Cropsey KL, Gamble KL. Sleep Strategies of Night-Shift Nurses on Days Off: Which Ones are Most Adaptive? Front Neurol 2014;5:277.

24. Burch JB, Tom J, Zhai Y, Criswell L, Leo E, Ogoussan K. Shiftwork impacts and adaptation among health care workers. Occupational Medicine 2009;59:159-66.

25. St Hilaire MA, Lammers-van der Holst HM, Chinoy ED, Isherwood CM, Duffy JF. Prediction of individual differences in circadian adaptation to night work among older adults: application of a mathematical model using individual sleep-wake and light exposure data. Chronobiol Int 2020;37:1404-11.

26. Barton J, Spelten E, Totterdell P, Smith L, Folkard S, Costa G. The Standard Shiftwork Index: A battery of questionnaires for assessing shiftwork-related problems. Work and Stress 1995;9:4-30.

27. Saksvik-Lehouillier I, Pallesen S, Bjorvatn B, Mageroy N, Folkard S. Towards a more comprehensive definition of shift work tolerance. In: Industrial Health; 2015:69-77.

28. Adan A, Almirall H. Horne & Östberg morningness-eveningness questionnaire: A reduced scale. Pers Indiv Differ 1991;12:241-53.

29. Takahashi M, Tanigawa T, Tachibana N, Mutou K, Kage Y, Smith L, Iso H. Modifying effects of perceived adaptation to shift work on health, wellbeing, and alertness on the job among nuclear power plant operators. Ind Health 2005;43:171-8.

30. Tucker P, Knowles SR. Review of studies that have used the Standard Shiftwork Index: evidence for the underlying model of shiftwork and health. Appl Ergon 2008;39:550-64.

31. Oyane NM, Pallesen S, Moen BE, Akerstedt T, Bjorvatn B. Associations between night work and anxiety, depression, insomnia, sleepiness and fatigue in a sample of Norwegian nurses. PLoS One 2013;8:e70228.

32. Natvik S, Bjorvatn B, Moen BE, Mageroy N, Sivertsen B, Pallesen S. Personality factors related to shift work tolerance in two- and three-shift workers. Appl Ergon 2011;42:719-24.

33. Netemeyer RG, Boles JS, McMurrian R. Development and Validation of Work-Family Conflict and Family-Work Conflict Scales. Journal of Applied Psychology 1996; 81:400-10.

34. Spielberger CD, Westberry LG, Grier KS, Greenfield G. The Police Stress Survey: Sources of stress in law enforcement. Tampa, FL: Human Resources Institute Monograph Series Three, No. 6; 1981.

35. Sugawara E, Nikaido H. Properties of AdeABC and AdeIJK efflux systems of Acinetobacter baumannii compared with those of the AcrAB-TolC system of Escherichia coli. Antimicrob Agents Chemother 2014;58:7250-7.

36. Camm AJ, Malik M, Bigger JT, Breithardt G, Cerutti S, Cohen RJ, Coumel P, Fallen EL, Kennedy HL, Kleiger RE, Lombardi F, Malliani A, Moss AJ, Rottman JN, Schmidt G, Schwartz PJ, Singer DH. Heart rate variability. Standards of measurement, physiological interpretation, and clinical use. Eur Heart J 1996;17:354-81.

37. Shaffer F, McCraty R, Zerr CL. A healthy heart is not a metronome: an integrative review of the heart's anatomy and heart rate variability. Front Psychol 2014;5:1-19.

38. Shaffer F, Ginsberg JP. An Overview of Heart Rate Variability Metrics and Norms. Front Public Health 2017;5:258.

39. Harris D, McNicoll L, Epstein-Lubow G, K.S. T. The bowel and beyond: the enteric nervous system in neurological disorders. Physiology & behavior 2017;176:139-48.

40. Bradley MM, Lang PJ. Emotion and motivation. Handbook of Psychophysiology 2000;2:602-42.

41. Lang PJ, Bradley MM. Emotion and the motivational brain. Biol Psychol 2010;84:437-50.

42. Thayer JF, Lane RD. A model of neurovisceral integration in emotion regulation and dysregulation. Journal of affective disorders 2000;61:201-16.

43. Zhou X, Ma Z, Zhang L, Zhou S, Wang J, Wang B, Fu W. Heart rate variability in the prediction of survival in patients with cancer: A systematic review and meta-analysis. J Psychosom Res 2016;89:20-5.

44. Aeschbacher S, Schoen T, Dorig L, Kreuzmann R, Neuhauser C, Schmidt-Trucksass A, Probst-Hensch NM, Risch M, Risch L, Conen D. Heart rate, heart rate variability and inflammatory biomarkers among young and healthy adults. Ann Med 2017;49:32-41.

45. Thayer JF, Yamamoto SS, Brosschot JF. The relationship of autonomic imbalance, heart rate variability and cardiovascular disease risk factors. Int J Cardiol 2010;141:122-31.

46. Tsuji H, Larson MG, Venditti FJ, Jr., Manders ES, Evans JC, Feldman CL, Levy D. Impact of reduced heart rate variability on risk for cardiac events. The Framingham Heart Study. Circulation 1996;94:2850-5.

47. Dekker JM, Crow RS, Folsom AR, Hannan PJ, Liao D, Swenne CA, Schouten EG. 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 2000;102:1239-44.

48. Tilea I, Petra D, Ardeleanu E, Hutanu A, Varga A. Clinical Conditions and Predictive Markers of Non-Dipper Profile in Hypertensive Patients. Acta Medica Marisiensis 2018;64:10-6.

49. Politano L, Palladino A, Nigro G, Scutifero M, Cozza V. Usefulness of heart rate variability as a predictor of sudden cardiac death in muscular dystrophies. Acta Myol 2008;27:114-22.

50. Kang MG, Koh SB, Cha BS, Park JK, Woo JM, Chang SJ. Association between job stress on heart rate variability and metabolic syndrome in shipyard male workers. Yonsei Med J 2004;45:838-46.

51. Koskinen T, Kahonen M, Jula A, Mattsson N, Laitinen T, Keltikangas-Jarvinen L, Viikari J, Valimaki I, Ronnemaa T, Raitakari OT. Metabolic syndrome and short-term heart rate variability in young adults. The cardiovascular risk in young Finns study. Diabet Med 2009;26:354-61.

52. Schroeder EB, Liao D, Chambless LE, Prineas RJ, Evans GW, Heiss G. Hypertension, blood pressure, and heart rate variability: The Atherosclerosis Risk in Communities (ARIC) study. Hypertension 2003;42:1106-11.

53. Nevels TL, Wirth MD, Ginsberg JP, McLain AC, Burch JB. The role of sleep and heart rate variability in metabolic syndrome: evidence from the Midlife in the United States study. Sleep 2023;46:1-11.

54. Andrew ME, Violanti JM, Gu JK, Fekedulegn D, Li S, Hartley TA, Charles LE, Mnatsakanova A, Miller DB, Burchfiel CM. Police work stressors and cardiac vagal control. Am J Hum Biol 2017;29.

55. Ramey SL, Perkhounkova Y, Hein M, Chung S, Franke WD, Anderson AA. Building Resilience in an Urban Police Department. J Occup Environ Med 2016;58:796-804.

56. Weltman G, Lamon J, Freedy E, Chartrand D. Police department personnel stress resilience training: an institutional case study. Glob Adv Health Med 2014;3:72-9.

57. Burch JB, Tom J, Zhai Y, Criswell L, Leo E, Ogoussan K. Shiftwork impacts and adaptation among health care workers. Occup Med (Lond) 2009;59:159-66.

58. Caruso CC. Negative impacts of shiftwork and long work hours. Rehabil Nurs 2014;39:16-25.

59. Folkard S, Lombardi DA, Tucker PT. Shiftwork: safety, sleepiness and sleep. Ind Health 2005;43:20-3.

60. McCanlies EC, Araia SK, Joseph PN, Mnatsakanova A, Andrew ME, Burchfiel CM, Violanti JM. C-reactive protein, Interleukin-6, and posttraumatic stress disorder symptomology in urban police officers. In: Cytokine: Elsevier Ltd; 2011:74-8.

61. Johnson TV, Abbasi A, Master VA. Systematic review of the evidence of a relationship between chronic psychosocial stress and C-reactive protein. Mol Diagn Ther 2013;17:147-64.

62. Carobene A, Braga F, Roraas T, Sandberg S, Bartlett WA. A systematic review of data on biological variation for alanine aminotransferase, aspartate aminotransferase and gamma-glutamyl transferase. Clinical Chemistry and Laboratory Medicine 2013;51:1997-2007.

63. Dunlap ME, Bhardwaj A, Hauptman PJ. Autonomic Modulation in Heart Failure: Ready for Prime Time? Curr Cardiol Rep 2015;17:103.

64. Wheat AL, Larkin KT. Biofeedback of heart rate variability and related physiology: a critical review. Appl Psychophysiol Biofeedback 2010;35:229-42.

65. Garcia AJ, 3rd, Koschnitzky JE, Dashevskiy T, Ramirez JM. Cardiorespiratory coupling in health and disease. Auton Neurosci 2013;175:26-37.

66. De Couck M, Gidron Y. Norms of vagal nerve activity, indexed by Heart Rate Variability, in cancer patients. Cancer Epidemiology 2013;37:737-41.

67. Lehrer P, Kaur K, Sharma A, Shah KB, Huseby R, Bhavsar J, Zhang YT. Heart Rate Variability Biofeedback Improves Emotional and Physical Health and Performance: A Systematic Review and Meta Analysis. Appl Psychophys Biof 2020;45:109-29.

68. Fournié C, Chouchou F, Dalleau G, Caderby T, Cabrera Q, Verkindt C. Heart rate variability biofeedback in chronic disease management: A systematic review. Complementary Therapies in Medicine 2021;60:1-13.

69. Cooper TM, McKinley PS, Seeman TE, Choo TH, Lee S, Sloan RP. Heart rate variability predicts levels of inflammatory markers: Evidence for the vagal anti-inflammatory pathway. Brain Behav Immun 2015;49:94-100.

70. Burch JB, Alexander M, Balte P, Sofge J, Winstead J, Kothandaraman V, Ginsberg JP. Shift Work and Heart Rate Variability Coherence: Pilot Study Among Nurses. Applied Psychophysiology and Biofeedback 2019;44:21-30.

Artifacts

Products

- Nevels, T.L, Burch, J.B., Wirth, M.E., Ginsberg, J.P., McLain, A.C., Andrew, M.E., Allsion, P., Fekedulegn, D., & Violanti, J.M. (2021). Shift work adaptation among police officers: The BCOPS study. *Chronobiology international*, 38, 6, 907-923. https://doi.org/10.1080/07420528.2021.1895197.
- Predicting line-1 DNA methylation levels using occupational stress and other factors in a longitudinal law enforcement cohort. Jonathan Wells, MHS, VCU SOPH Department of Epidemiology Seminar 03/12/2024.
- Longitudinal Effect of Shiftwork on Heart Rate Variability in the Buffalo Cardio-Metabolic Occupational Police Stress (BCOPS) Study. James B. Burch, Jonathon Jacobs, Jonathan L. Wells, Desta Fekedulegn, Robert A. Perera, Torrance L. Nevels, Michael Wirth, Michael E. Andrew, John M. Violanti. 27th Conference of the European Sleep Research Society, Seville, Spain, 24-27 September, 2024.
- Adaptation to Shift work (2023). John M Violanti, PhD. IACP Annual Conference, San Diego, CA.
- Adaptation to Shift work: factors for maladapting (2023). John M Violanti, PhD, NIJ conference, Washington , DC
- Lessons Learned from Promoting Officer Health and Wellness (2023). NIJ Conference panel. Shift work adaptation and suggestions. John M. Violanti, PhD.

Data Sets

- Shift work survey database identifying psychosocial adaptive and maladaptive behaviors associated with shift work.
- Database containing physiological and biological factors involved in shift work adaptation.