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Original paper

Metabolic syndrome and salivary cortisol: Is there dysregulation among a group of active duty urban police officers?☆,☆☆

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ABSTRACT

Objective: Examine metabolic syndrome risk and cortisol patterns in an actively employed group of urban police officers.
Methods: A total of 102 actively employed Upstate New York police officers were randomly selected. Metabolic syndrome risk factor determinations were obtained during a scheduled clinic visit and salivary cortisol measures were subsequently obtained over the next 24 h.
Results: 24% of male police offers demonstrated metabolic syndrome as defined by the National Cholesterol Education Program guidelines. Only one female officer met the criteria for metabolic syndrome; however, she declined to participate in the cortisol portion of the study. Among male officers were the most prevalent risk factors, while female officers most often exhibited as the most commonly identified risk factors. The various cortisol measures produced mixed results. Area under the curve cortisol did demonstrate moderate dysregulation.
Conclusion: Cortisol dysregulation is evident among the male officers with metabolic syndrome who participated in the study. Of interest among those officers with only two syndrome characteristics, dysregulation of awakening area under the curve cortisol measures was also apparent. Continued monitoring of the officer population for manifest diabetic and cardiovascular disease should be undertaken.

1. Introduction

The high-risk occupations, such as police work, can place officers at increased risk for mental as well as physical disorders, in addition to the long-term sequelae of mental and physical disorders given the nature of the stressor inherent in that form of employment. The Buffalo Cardio-Metabolic Occupational Police Stress (BCOPS) study, a population-based occupational cohort study of Buffalo, New York police officers, was undertaken to evaluate the psychological and physiological health of the officers, specifically stress and subclinical measures of cardiovascular and metabolic disease.

The relationship(s) between insulin resistance (metabolic syndrome) and sympathetic nervous system activity are not yet fully understood. Hypothalamic–pituitary–adrenal (HPA) axis dysregulation can contribute to central adiposity, hypertension and dyslipidemia, all key components of metabolic syndrome [1,2]. Cortisol dysregulation can occur as cortisol production that is in excess of the characteristic diurnal daily cortisol pattern, or in the form of dysregulation that occurs when levels that are lower than normal for any given time period of the day and thus not allowing the individual to achieve an appropriate diurnal daily response [3].

Given the importance of identifying at-risk individuals who may not yet be aware of the diagnosis of metabolic syndrome, it is prudent that these individuals be identified to allow for preventive interventions to be initiated as early as possible in the metabolic syndrome trajectory in an attempt to forestall the clinical presence of overt diabetes and cardiovascular disease [4,5]. The current study examined BCOPS study demographic characteristics, as well

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as metabolic syndrome and cortisol patterns within this population with the hypothesis that there will be a likelihood of dysregulated salivary cortisol responses (awakening and area under the curve cortisol) in those individuals who demonstrate a greater number of constituent metabolic syndrome parameters than those with fewer diagnostic constituent parameters.

2. Review of literature

2.1. Metabolic syndrome background

The emergence of the metabolic syndrome is an example of a non-communicable disease state that contributes to the morbidity and mortality of modern society through improvements in socioeconomic and demographic characteristics of the world's population. Excess cortisol production can contribute to the hyperinsulinemic state that is integral to the metabolic syndrome process [1,2].

Syndrome X, the initial term used to define early work on metabolic syndrome, was based on his physiologic research that had documented resistance to the tissue effects of insulin as a central feature of obesity as well as a fundamental precursor to the development of type 2 diabetes, hypertension, and dyslipidemia [4]. The underlying factor is the resistance of peripheral tissues, mainly skeletal muscle, to insulin-mediated glucose disposal, leading to hyperinsulinemia.

Describing the metabolic syndrome as a clustering of two or more cardiovascular disease risk factors, Reaven determined the metabolic syndrome risk factors as: visceral obesity, hyperinsulinemia, impaired glucose tolerance, dyslipidemia, and hypertension [4]. Features of metabolic syndrome may be present for up to 10 years prior to the onset of overt hyperglycemia. While it is not disputed that these lifestyle and health risk factors play a role in the development of cardiovascular disease, they have not been deemed causal in the Reaven hypothesis [4].

Given the clinical and public health importance of identifying high-risk individuals who may not yet be aware of the diagnosis of metabolic syndrome, the World Health Organization (WHO) in 1998 and the National Cholesterol Education Program Adult Treatment Panel III (NCEP ATP III) in 2001 put forth guidelines for the proposed clinical definitions of the syndrome in adults to aid in diagnosis and suggestion of preventive interventions for this syndrome [6–8].

Much debate has surrounded whether metabolic syndrome offers more to the diagnostic realm beyond the sum of its parts. Much of the question surrounds whether or not the construct of metabolic syndrome reflects one pathogenic pathway or is a combination of more than one biophysiologic pathway. Sobel suggests that if healthcare abandons the overarching concept of metabolic syndrome, it will do a great disservice to the public's health [5]. While all of the debate over metabolic syndrome is not simply semantic, the American Heart Association (AHA) and National Heart, Blood, and Lung Institute (NHBLI) have also taken a stand on whether or not metabolic syndrome exists. In response to the American Diabetes Association (ADA) position that metabolic syndrome is a poorly defined syndrome which is inconsistently used and in need of further research, the AHA and NHBLI suggest that the syndrome is robust, clinically useful, and requires attention in diagnosis and treatment [9].

Ford et al. estimated the prevalence of metabolic syndrome utilizing the NCEP guidelines (Table 1) and the Third National Health and Nutrition Examination Survey (NHANES) 1988–1994 [10]. The unadjusted prevalence rate of metabolic syndrome was estimated at 21.8%, while the age-adjusted prevalence rate was 23.7%. The prevalence rates obtained from the NHANES data increased with increasing age. Utilizing year 2000 census data and NCEP ATP III guidelines, Ford et al. estimated that at least 64 million Americans are affected with metabolic syndrome [10]. In 2003 the American Diabetes Association recommended lowering the glucose threshold for the diagnosis of impaired fasting glucose from 110 to 100 mg/dL. At the time of the change, the ADA postulated that the prevalence of metabolic syndrome would increase by approximately 5%.

Table 1
NCEP guidelines: risk factors and parameters used in defining metabolic syndrome.

BP parameter
Hypertension (DBP ≥85 mmHg, SBP ≥130 mmHg)
Central obesity parameter
Waist ≥102 cm ♂, 88 cm ♀
Dyslipidemia parameter
HDL ≤40 mg/dL ♂, 50 mg/dL ♀
Triglycerides ≥150 mg/dL
Insulin-related parameter
Glucose ≥110 mg/dL or known diabetes

3 of 5 parameters required for diagnosis [7].

NHANES III data, analyzed to determine the prevalence of component traits of metabolic syndrome found that waist circumference greater than the designated cut-point demonstrated a nearly 50% prevalence rate in females and a 30% prevalence rate in male participants. High triglycerides were found to have a prevalence rate of approximately 35% in men and 25% in women. Prevalence rates of low high density lipoprotein cholesterol were found in approximately 35% of men and 38% of women. Hypertension was more prevalent in men (∼40%) than women (∼30%). Impaired fasting glucose or overt diabetes occurred more frequently in men (∼15%) versus women (10%) [10,11].

2.2. Cortisol and allostatic theory

Cortisol, an essential hormone to human existence, is sometimes termed as the body's natural stress fighter [1]. Cortisol has many active functions within the body. Regulation of glucose and blood pressure, insulin release from the liver, as well as immune and inflammatory responses within the body are but a few of the important functions of cortisol. Without cortisol, these functions that are autonomic and essential to daily existence would not occur within the body. Cortisol is delineated by bound and unbound measures, with 10–20% of circulating cortisol loosely attached to albumin and 70% or 80% bound within the sera to transcortin. The remaining 10% is unbound [1,12].

When the body's internal functions do not allow cortisol levels to return to baseline, the stress response remains activated and this can produce consequences within the body. Negative or detrimental effects of prolonged cortisol elevations include impaired mental function, suppressed thyroid gland function, increases in blood glucose levels, increased blood pressure, as well as increased abdominal fat. These effects underscore the need for the body to reset itself to baseline or homeostasis after invoking the stress response within the body [1,12,13].

Fig. 1 represents the negative feedback loop of the hypothalamic–pituitary–adrenal axis. The negative feedback loop of the HPA axis operates through monitoring of circulating levels of cortisol. Elevated levels of cortisol, when present within the body, leads the body to suppress corticotropin releasing hormone (CRH) and adrenocorticotropic hormone (ACTH) release from the hypothalamus and pituitary respectively. This suppression ultimately leads to reduced cortisol production. Hormone production of CRH and ACTH vary in output throughout the day as well, with the lowest production occurring during the diurnal trough [12].

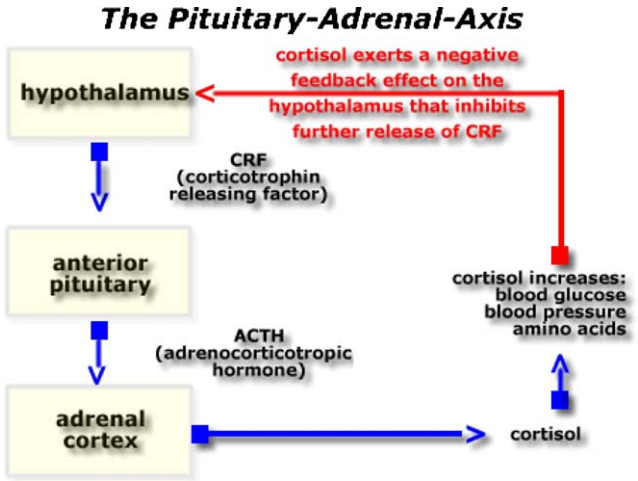

Fig. 1. Negative feedback loop of the HPA axis.

Diurnal cortisol rhythm characteristically peaks shortly after awakening and then falls throughout the day. With a biological half-life of approximately 80 min, cortisol production is typically highest in the morning prior to awakening, decreasing progressively throughout the day, and reaches the lowest levels three to five hours after the onset of sleep [13]. Cortisol levels that are divergent from the expected diurnal pattern for any given time period of the day, may place an individual at risk for a pathologic process that could predispose the individual to illness [3].

McEwen describes the temporal dynamics of HPA axis to stressors [14]. Three phases of activity consist of basal activity, stress reactivity, and a stress recovery phase. The basal activity phase reveals unstimulated, non-stressed HPA activity. The stress reactivity phase reflects the cortisol increase from baseline levels following the exposure to a stressor. The stress recovery phase reflects the return of cortisol levels to baseline following the retreat of the stressor.

Allostatic load (AL) is produced in the body as a result of excessive environmental or psychological pressures [15]. AL provides a framework for investigating the ability of an individual to self-regulate in an attempt to return to homeostasis and maintain overall stability, which is called allostasis. AL, if allowed to manifest without remediation, contributes to the worsening of a variety of conditions, including metabolic syndrome. AL and metabolic syndrome share several common variables which include adverse levels of blood pressure, waist circumference, cholesterol parameters, and measures of glucose tolerance.

3. Study subjects

The study population includes a homogeneous group of sworn Buffalo, New York police officers who were selected via a random sampling design stratified by gender utilizing a computerized random numbers table ($n = 102$; 41 females and 61 males). No specific inclusion or exclusion criteria were used for the study, other than the participant would be a sworn police officer and willing to participate in the study. The BCOPS study was reviewed by the University at Buffalo, The State University of New York Institutional Human Subjects Review Board, as well as the National Institute for Occupational Safety and Health Human Subjects Review Board. Informed consent was obtained from all participants prior to interview and clinical examination.

4. Materials and methods

Given the importance of early identification of those individuals with metabolic syndrome, the BCOPS study presents a unique opportunity to identify individuals within an occupational cohort who may not be aware that they are currently at risk for metabolic syndrome. The current study hypothesizes that those individuals with three or more metabolic syndrome parameters will demonstrate a dysregulated first waking and waking area under the curve cortisol response. Given the threat of cortisol dysregulation to further exacerbate glucose, blood pressure, weight or cholesterol abnormalities, a metabolic syndrome risk assessment, as well as an appraisal of the cortisol output of those with metabolic syndrome risk factors was undertaken in this occupational cohort of Buffalo, NY police officers.

Data were collected (1998–2003) as part of the BCOPS study protocol which included the baseline and pilot study periods. Cross-sectional analytic methods were utilized to investigate the associations between metabolic syndrome and salivary cortisol patterns. Sworn Buffalo, New York police officers who were randomly selected via a stratified sampling technique and who underwent a comprehensive baseline examination during the study period were included in the analysis. This baseline examination included biophysical measures, psychologic rating scales, and personal demographic data.

5. Data collection

The BCOPS study consisted of interviewer administered questionnaires conducted by trained staff and self-report questionnaires which the officer completed at home prior to the initial clinic visit. The questionnaires included demographic and employment data, stress inventories, depression and life event scales. Clinical examinations included salivary cortisol levels, orthostatic blood pressures, abdominal height and height/weight for body mass index calculations.

Salivary cortisol collection is a well-validated measure of cortisol and strongly reflects free or unbound serum cortisol [16]. During a repeat examination between 2001 and 2003, 87 participants received instruction and demonstration of proper collection technique as well as written directions on the saliva collection technique. Prior to salivary cortisol sampling, participants were screened for medication usage. Those participants who indicated prescription steroid usage or the current use of anticoagulants (blood thinners) were subsequently eliminated from the salivary cortisol pool due to the potential for their medication usage to impact salivary cortisol measures. Adequate salivary samples were reviewed, stored, and subsequently sent to the Technical University of Dresden for laboratory analysis using a chemiluminescence immunoassay. A commercially available salivary collection device, *Salivette*, was utilized for the BCOPS population.

Salivary cortisol levels were collected at home upon awakening and at 15, 30, 45, and 60 min after awakening. This methodology works well for police because of the high variability in sleep–wake times [17]. The awakening area under the curve cortisol measure consisted of the initial awakening cortisol measure, as well as the repeated measures every 15 min for one hour after awakening (AUC waking).

Metabolic syndrome was determined utilizing NCEP ATP III guidelines. The NCEP ATP III guidelines represent what is most often found in the literature on metabolic syndrome, as well as the measure that includes easily obtainable clinical measures. Metabolic syndrome is present if three or more of the constituent

Table 2
BCOPS 1999–2003: metabolic syndrome demographic and lifestyle characteristics.

Characteristics	Number at risk	Number with metabolic syndrome	Percentage with metabolic syndrome	*p* value*
Gender				
Male	61	15	24.6	
Female	41	1	2.4	0.003*
Race				
White	76	10	13.2	
Afr. American	19	2	10.5	
Hispanic	5	4	80.0	0.001*
Age				
<40	29	7	24.1	
40–49	45	5	11.1	
>50	26	3	11.5	0.358
Education				
High School or less	16	4	25.0	
<4 years college	29	6	20.7	
>4 years college	50	5	10.0	0.019*
Marital status				
Single	20	3	15.0	
Married	65	12	18.5	
Divorced	15	1	6.7	0.769
Smoking status				
Current	20	3	13.6	
Former	34	6	15.8	
Never	47	6	12.8	0.333
Alcoholic drinks				
0	26	6	23.1	
<1	23	1	4.3	
1–5	35	5	14.3	
≥6	18	4	22.2	0.288

* Significance at the 0.05 level.

parameters are present [7]. Serum insulin measures were not obtained during the clinic visits, therefore without this important insulin measure, WHO criteria could not be employed to ascertain the presence or absence of the syndrome.

6. Analysis plan

The aim of this study was to explore the cross-sectional relationship between metabolic syndrome and salivary cortisol levels. Utilizing a level of significance at the 0.05 level, analysis of variance was used to determine the relationship between metabolic syndrome and awakening salivary cortisol, as well as AUC cortisol measures. Demographic data will include the 102 participants for descriptive purposes, while the salivary data will include the 87 officers who provided salivary cortisol samples.

7. Results

The number of male and female officers included in this study is nearly equal due to oversampling of the female officers. The majority of the officers were Caucasian (76%), with an average age of 43.9 years. Nearly 55% of both the male and female officers completed 4 or more years of college education. Patrol officers represented fifty percent of the total sample. The average years in service to the City of Buffalo, New York police force was 14.9 years.

Among demographic and lifestyle characteristics, education, race, and gender demonstrated statistical differences when examining how prevalence of the syndrome varied across categories of these characteristics (Table 2). It should be noted that only one female fulfilled the criteria for metabolic syndrome. The overall prevalence of metabolic syndrome is approximately 16% utilizing the NCEP guidelines. Two percent of female participants ($n = 1$) within the study cohort met the NCEP criteria for metabolic syndrome, while 24.6% of male participants ($n = 15$) met the diagnostic criteria.

Table 3 describes the average values of the constituent parameters of metabolic syndrome in three groupings: those with the least evidence of the metabolic syndrome (zero or one parameters), those who are likely to develop metabolic syndrome (two constituent parameters), and those who meet the NCEP definition of metabolic syndrome (three or more constituent parameters). While the category of "likely to develop" is not

Table 3
BCOPS 1999–2003: mean $\bar{x}$ levels of metabolic syndrome constituent parameters by number of constituent parameters and gender.

Component	$\bar{x}$ few met syn 0–1 parameters (SD)	$\bar{x}$ likely to develop met syn 2 parameters (SD)	$\bar{x}$ met syn present 3 or more parameters (SD)	*p* value*
	n = 36	*n* = 4	*n* = 1	
Female				
Triglycerides	69.00 (28.8)	89.50 (70.5)	109.00 (0)	0.310
HDL-C	57.02 (11.9)	42.90 (5.5)	33.00 (0)	0.016
Glucose	87.28 (7.7)	88.00 (6.2)	100.00 (0)	0.267
Waist circ+	79.20 (9.9)	86.50 (7.2)	103.00 (0)	0.031
Mean SBP	106.4 (10.4)	106.3 (13.8)	109.00 (0)	0.971
Mean DBP	68.1 (8.3)	65.8 (7.2)	69.0 (0)	0.859
	n = 35	*n* = 11	*n* = 15	*p* value*
Men				
Triglycerides	77.57 (28.0)	139.18 (77.2)	166.87 (65.2)	0.001
HDL-C	50.79 (12.9)	41.00 (5.6)	35.05 (3.9)	0.001
Glucose	92.43 (11.0)	96.55 (6.5)	102.60 (20.7)	0.057
Waist circ+	91.92 (8.3)	102.49 (7.9)	105.66 (8.8)	0.001
Mean SBP	114.11 (10.2)	118.73 (14.5)	125.4 (10.6)	0.007
Mean DBP	70.86 (8.9)	78.8 (8.1)	75.80 (11.6)	0.035
	n = 71	*n* = 15	*n* = 16	*p* value*
Total				
Triglycerides	73.23 (29.0)	125.93 (76.4)	163.2 (64.6)	0.001
HDL-C	53.95 (12.7)	41.51 (5.4)	34.93 (3.8)	0.001
Glucose	89.92 (9.8)	94.27 (7.3)	102.44 (20.0)	0.001
Waist circ+	85.47 (11.1)	98.23 (10.4)	105.49 (8.6)	0.001
Mean SBP	110.21 (10.9)	115.40 (14.9)	124.38 (11.0)	0.001
Mean DBP	69.45 (8.7)	75.33 (11.3)	75.38 (11.3)	0.015

+ waist circumference-measurement in centimeters; met syn: metabolic syndrome; SBP: systolic BP measured in mmHg; and DBP: diastolic BP measured in mmHg.
* ANOVA significance.

included in the NCEP nomenclature, recent recommendations from the American Diabetes Association suggest that screening for pre-diabetic conditions, such as metabolic syndrome should begin whenever risk factors are present [18]. Female participants demonstrated significant differences across the constituent parameter categories for HDL-C and waist circumference. Male participants demonstrated differences across all constituent component variable categories except for glucose, which was marginally significant. As a total participant group, significant differences exist for all constituent parameters when comparing across the categories of metabolic syndrome. While trends were similar for males and females within the study groupings, statistical significance may have failed to achieve significance due to only having one female in the metabolic syndrome category.

First waking salivary cortisol samples were available to be analyzed for 83 of the 100 officers in the study. Diurnal cortisol measures were available for 57 of the 100 study subjects, while waking area under the curve measures were available for 60 of the subjects. Reasons cited for those who failed to submit a full set of cortisol samples included simply forgetting to obtain the sample, taking medications at the wrong time of the day in relation to the salivary sample, receiving dental medication, or refusal to complete the study protocol.

The mean waking salivary cortisol level for the entire group of officers was 14.04 nmol/L (SD ± 10.39). Female officers exhibited a mean waking salivary cortisol level of 10.80 nmol/L (SD ± 6.56), while their male counterparts demonstrated a mean waking cortisol of 16.28 nmol/L (SD ± 11.95). The gender difference between mean waking cortisol values was statistically significant ($F[1, 81] = 5.910$; $p = 0.017$).

Mean waking cortisol measures and complete physiologic measures of the prevalent constituent parameters that would allow for categorization of metabolic syndrome risk were available for 66 of the participants. The only female who met the NCEP criteria for metabolic syndrome did not provide any salivary cortisol samples. Further cortisol analyses include only males with NCEP diagnostic metabolic syndrome.

Mean waking salivary cortisol values were analyzed across the parameter groupings for metabolic syndrome. Participants with zero or one of the prevalent syndrome parameters ($n = 49$) demonstrated a mean waking cortisol of 12.93 nmol/L (SD ± 9.03), while those with two diagnostic parameters ($n = 9$) demonstrated a mean value 14.18 nmol/L (SD ± 11.24). Officers with NCEP diagnostic metabolic syndrome and waking salivary cortisol measures ($n = 8$) demonstrated a mean waking salivary cortisol of 12.76 nmol/L (SD ± 9.32). No statistically significant difference was found between the categories ($F[2, 63] = 0.072$; $p = 0.930$, partial $\eta = 0.002$).

Cumulative area under the curve (AUC) analysis of waking salivary cortisol measures and metabolic syndrome categories demonstrated an overall non-significant finding ($F[2, 50] = 1.468$; $p = 0.240$). Linear trend analysis also failed to reveal a significant trend in mean waking AUC salivary cortisol across categories of metabolic syndrome ($p = 0.19$). Fig. 2 illustrates the mean waking salivary cortisol measures in 15 min time increments from awakening. Those individuals with one or less metabolic syndrome constituent parameters exhibit a cortisol curve that most closely resembles the expected waking AUC response. Those with two constituent parameters begin to exhibit some dysregulation of the cortisol response when mean values are plotted by the same time increments. Rather than the distinctive expected rise that should occur after awakening and then begin to wane prior to the mid-day meal time, those with two constituent parameters demonstrated a down-sloping after awakening that attenuated only slightly at the 30 and 45 min post-awakening marks. Those individuals with three or more constituent parameters demonstrated a negative

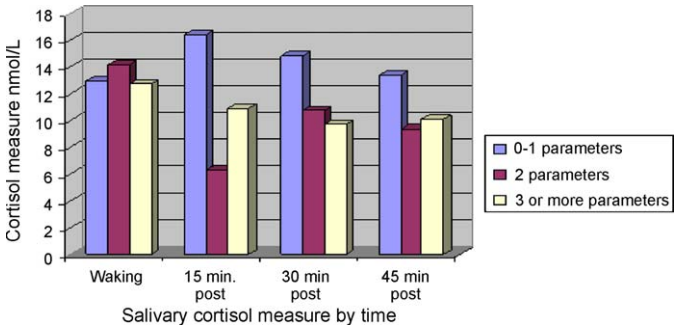

Fig. 2. BCOPS 1999–2003: unadjusted salivary cortisol levels in men by 15 min time increments (waking AUC response) and number of metabolic syndrome parameters.

slope from the waking measure throughout the hour post-awakening that encompasses the AUC measure.

The 15 min post-awakening cortisol measure did demonstrate significant findings across the metabolic syndrome parameter groupings $F(2, 56) = 2.678$, $p = 0.07$, partial $\eta = 0.087$. The linear trend across metabolic syndrome categories was not significant. The 30 and 45 min post-awakening measures failed to achieve statistical significance when analyzed in isolation across metabolic syndrome categories.

Fifty participants completed the full diurnal set of salivary cortisol measures. These measures encompass the waking measure, the waking AUC measure, lunch, dinner and a final measure for the day that is completed before retiring for the evening. Diurnal cortisol measures were log transformed prior to analysis. Five of the participants with NCEP diagnostic metabolic syndrome had complete measures, while six of those with two constituent parameters and 39 individuals with one or less parameters encompass this analysis. Diurnal AUC salivary cortisol measures and metabolic syndrome categories did not demonstrate a statistically significant association $F(2, 47) = 1.711$, $p = 0.192$, partial $\eta = 0.61$. Again, the mean diurnal AUC values demonstrate a diminished slope for the mean of values when examined across diagnostic categories. The linear trend analysis across categories of metabolic syndrome demonstrated a nearly significant result ($p = 0.07$). Significant differences were noted in mean diurnal AUC values between those with 0–1 constituent parameters compared to those with 3 or more parameters present that would be indicative of metabolic syndrome.

8. Discussion

The aim of this current analysis was to assess the prevalence of metabolic syndrome within an occupational cohort of Buffalo, New York police officers as well as associations between metabolic syndrome and a variety of salivary cortisol measures. It was hypothesized that the salivary cortisol responses would be dysregulated in individuals with metabolic syndrome, the current findings present mixed results. Similar mixed results have been reported in previously published cortisol and metabolic syndrome studies [19,20].

The overall prevalence of metabolic syndrome within this police cohort is approximately 16%. The prevalence rate within this occupational group is lower than that of other community based population studies such as NHANES 1988–1994, which reported an unadjusted prevalence rate of approximately 22% in the general population [21]. Humbarger et al. demonstrated a prevalence rate of 27.4% in a Texas police cohort where the average age of the participants was 36.2 years [22]. The metabolic syndrome rate among BCOPS male officers (~26%) is similar to that of male officers in the Texas police cohort. The overall lower prevalence

rate of metabolic syndrome in the cohort may represent a healthier policing force [23] or simply be a result of decreasing sample size as components of the syndrome are considered for analysis.

Utilizing years of service, Caucasian participants with metabolic syndrome were most often on the job 21 or more years, while among the non-Caucasian participants those with metabolic syndrome were most often on the job 11–20 years. This finding is similar to that of Ford et al., who reported increasing prevalence of metabolic syndrome across increasing age categories among the NHANES population [21]. Among all participants in BCOPS with measures that were diagnostic for metabolic syndrome, more than half of those with the syndrome had been on the job for 21 or more years.

Examining mean levels of the constituent parameters of metabolic syndrome within this policing cohort, statistically significant differences were found between the parameter means across the levels of the syndrome that were utilized in this study. The parameters that exceeded the NCEP cutpoints most often for both genders included decreased HDL and increased waist circumference. Increased waist circumference and lower HDL cholesterol levels are consistent with findings from NHANES III data that examined the prevalence of component traits of metabolic syndrome [10,11]. Impaired fasting glucose in the BCOPS group occurred more frequently in males (36.1% prevalence) compared to females (5%), however the prevalence rates among male participants in BCOPS is higher than that reported in NHANES III at approximately 15% [10,11].

As a total participant group, all constituent parameters of the metabolic syndrome were statistically significant across the gradient of parameters (0–1, 2, 3 or >). When stratified by gender, all parameters achieved statistical significance amongst the male officers, while among the female participants decreased HDL cholesterol and waist circumference were the parameters to achieve statistical significance across the syndrome gradient. This finding should be interpreted with caution due to the small number of participants in the probable and diagnostic metabolic syndrome categories. However, as an occupational cohort, differences in constituent parameters should be considered giving special risk attention to females who may possess central obesity and low HDL cholesterol levels. Among males, all parameters were significant and once one constituent parameter is identified, others should be evaluated in that same individual [18].

Cortisol values within this policing cohort produced mixed results when considering metabolic syndrome in the analysis. Mean waking salivary cortisol among the three categories of metabolic syndrome resulted in no statistically significant difference among the groups. This finding is similar to that found in the Whitehall II study, which found that salivary cortisol measures were similar between cases and controls [24]. This reflects a minor suppression of mean waking salivary cortisol measures in those with metabolic syndrome compared to those without the syndrome.

Area under the curve salivary cortisol analysis did present some interesting findings. Waking area under the curve analysis and metabolic syndrome categories demonstrated an overall non-significant finding; however a downward trend for the mean of the waking values over time was noted. Each of the incremental measures that produce the waking AUC cortisol response when examined across metabolic syndrome categories provided an interesting illustration of the cortisol trend. Those individuals with one or fewer constituent parameters presented a cortisol curve that most closely resembles the expected waking peak and attenuation prior to the mid-day meal. Those participants with two constituent parameters demonstrated a more negative post-awakening slope that attenuated nearly one hour post-awakening. Those meeting the diagnostic criterion for metabolic syndrome demonstrated a negative slope from awakening to the last incremental waking AUC measure taken at 60 min post-awakening. Assessment of the relationship between diurnal area under the curve analysis and metabolic syndrome category when examined in an overall fashion did not demonstrate statistically significant findings.

This finding is consistent with the postulated pathway for disease development in that an unfettered physiologic response, whether in response to environmental stressors which are new to the individual or a chronic stressor, allows for allostatic overload to occur. Allostatic overload can lead to worsening of psychologic stressors if present or in the presence of metabolic abnormalities, such as hyperglycemia, hypertension, or dyslipidemia, can lead to a worsening of hematologic values or a new onset of the aforementioned hematologic abnormalities that were previously well controlled by the internal mechanisms of the body (i.e. homeostasis).

Given the importance of early identification of those with metabolic syndrome, this study lends support to the suggestion of Reaven [4], Sobel [5], and Grundy [9]. When one of the syndrome components has been identified, a diligent search should be undertaken or approached in an on-going manner given that the cortisol results from this study provided preliminary evidence that dysregulation was found when two of the constituent parameters were present. Whether or not salivary cortisol measures are practical in a primary care setting remains to be seen, however the findings from BCOPS Study suggest that in a high-stress occupation, healthcare providers need to remain diligent in the search for medical sequelae of the occupation.

In any cross-sectional study, limitations exist. The sample size utilized in this study was small ($N = 102$) and numbers diminish as increasing numbers of metabolic syndrome and cortisol measures are added. However, the methodology involved random selection of participants thus increasing the likelihood that participating officers were representative of all officers working in the department. Mapping salivary cortisol and metabolic syndrome risk over time in this officer group would certainly prove beneficial in the future for measuring the long-term health effects of high-stress occupation.

Cross-sectional studies cannot assess the temporality of the exposure and the outcome (dysregulated cortisol). The selection process diminishes the risk of participant selection bias; however, it does not reduce the risk of the healthy worker effect which could bias the results toward the null resulting in non-significant findings when examining the data for dysregulated cortisol responses [25].

This study includes well established measures of metabolic syndrome and salivary cortisol. These measures were obtained utilizing a standardized laboratory protocol and the salivary cortisol measures that were returned to NIOSH demonstrated a high level of cooperation among the officers in the study [26].

In summary, metabolic syndrome was found to be less prevalent within this police cohort compared to that reported for the general population. Associations between salivary cortisol measures and the metabolic syndrome revealed mixed results. Still, a clear demonstration of blunted cortisol responses across the categories of constituent metabolic syndrome parameters was present. Additionally, repeat measures of the constituent parameters across points in the future would allow for an evaluation of which parameters were subject to potential development in those individuals who had not previously exhibited those particular parameters. Additional prospective studies with sufficient sample size may be warranted to further clarify the association between cortisol dysregulation and metabolic syndrome parameters as well as the potential biologic mechanisms involved.

Conflict of interest

None.

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